FORESTRY HORTICULTURAL AND AGRICULTURE MANAGEMENT: INTERNATIONAL AND NATIONAL STRATEGIC GUIDELINES OF SUSTAINABLE SPATIAL DEVELOPMENT

According to the scientific edition
Candidate of Economics Sciences,
Professor T.I. Melnyk

RS Global

Warsaw 2024

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MODERN METHODS OF OBTAINING AND ADAPTATION OF PINUS SYLVESTRIS L. PLANTING MATERIAL UNDER THE CONDITIONS OF THE BRANCH "SUMY FOREST FARM" STATE ENTERPRISE "FORES OF UKRAINE"

Melnyk Andrii
Doctor of Agricultural Sciences, Professor
ORCID ID: 0000-0001-7318-6262

Dudka Anhelina
Assistant, PhD
Sumy National Agricultural University, Ukraine
ORCID ID: 0000-0001-9444-4339

Introduction. Scots pine (*Pinus sylvestris L.*) is the most common pine found throughout Eurasia. In the EU member states, its share is approximately 20 % of the area of industrial forests and is of great importance as a type of wood, especially in the north of Europe [18]. Scots pine (*Pinus sylvestris L.*) is an important commercial conifer species in many European countries. In Great Britain it accounts for approximately 16 percent of the total conifer stock and up to 30 percent in the north and north-east of Scotland [17]. Thanks to its adaptation to different climatic conditions, it is a fairly common tree species in the world and in Ukraine, because it can grow both in forests and in piles, and it is one of the most commercially important species of wood in Europe. Despite such a wide distribution of the breed in various forest vegetation conditions, it is noted that the best-quality wood of Scots pine is formed mostly in subforests, which occupy about 1,300 thousand hectares of the territory of Ukraine [32]. Scots pine is also capable of forming productive stands in conditions of various edaphotopes, which are characterized by high indicators of stability and durability [29].

Scots pine has a range that covers all of Scandinavia, the northeastern regions of European Russia and Siberia, extending eastward to the Seas of Okhotsk and Japan. In Poland, it is the dominant forest species, covering 66,5 % of the total forest area [39]. In the Caucasus, it is found from sea level to mountain peaks up to about 2,700 m above sea level, in Poland, it is found mainly in lowland areas, reaching a height of 700 m in the Carpathians, although individual trees are found up to 1,100 m above sea level. It is also the most important forest-forming species in Poland with great potential for use in the woodworking industry [14].

Pine wood is valued and widely used not only due to its availability, but also due to its physical and mechanical properties. Its technical properties depend, among other things, on its geographical origin. One of the scientists [20] showed that the properties of pine wood deteriorate in the direction from north to south, and there is no clear trend along the east-west axis. Thus, it is generally believed that pine

A number of factors affect the technical quality of wood. It depends mainly on the geographical location, the type of local growth and the quality of the planting material [15]. Genetics, environment and human factors can determine the dendrometric characteristics of trees, properties and structure of wood. Genotype can affect wood quality. The genome can demonstrate phenotypic features and help determine resistance to internal and external factors [24, 25].

Scots pine is a species with a very wide natural range. Because it grows in different climatic and soil conditions, it shows great variation in the morphology, productivity and quality of its wood.

Scots pine is a medium-sized coniferous tree, reaching 30–35 m in height, only in exceptional cases more than 40 m, and 50–130 cm in diameter. The lifespan of this pine is about 250 years, sometimes up to 400 years. Develops an open crown with spreading branches. The stem is characterized by a reddish-orange bark in the upper part. The leaves are needle-like, blue-green in color, 5–7 cm long, arranged in pairs. Male flowers are numerous, clustered at the base of new shoots and yellow or pink when mature. Female flowers appear at the tips of the shoots and turn pinkish-purple when pollinated. Cones develop the following year after pollination, the size of which reaches 5–8 cm. In autumn, the cones open and throw out winged seeds that are carried by the wind [45].

Scots pine is one of the most commercially important tree species, especially in northern Europe. It is used for the production of pulp and lumber (buildings, structures, furniture, etc.). The wood is easily processed and is one of the strongest conifers. Pine is a pioneer species and grows on poor soils; therefore, it is also planted for reclamation and anti-erosion purposes and as a windbreak [5]. It is often used in dendrochronology, the study of annual tree rings, because it is relatively long-lived and often grows in marginal conditions where small variations in temperature and/or moisture can have a marked effect on its growth and ring size.

In Scandinavia, resin is extracted from Scots pine for the production of "Stockholm resin". This product has traditionally been used as a wood and rope wax to weatherproof, weatherproof, or improve grip (e.g. applied to baseball bat handles or Nordic style skis). Nowadays, this tar has been replaced by synthetic products that are easier to produce industrially. wood from the northern parts is better, having greater density and strength [13].

Products derived from trees have played an important role in driving technological progress throughout human history. A key example of such products is the resin produced by coniferous trees. Pine tar and pitch were used to cover the seams of wooden ships and vessels, etc. For centuries, pine-based products have been widely used in adhesives, soaps, water-repellent surface coatings for ropes, construction, and even art [1].

In the United States, Scots pines are planted to grow as Christmas trees. The Scottish Highlands were once covered with forests consisting mainly of Scots pine. They are cut down mainly for the needs of wood and creating pastures for livestock. Only small patches of ancient pine forests remain in Scotland, covering about 17,000 hectares [37].

Despite various silvicultural alternatives used to guarantee the sustainability of plantations and various aspects of ecosystems [11], growing potentially valuable trees with high-quality trunk wood remains one of the main tasks of traditional forest management. Forest managers use silvicultural techniques to maximize tree growth. At the local and global levels, in the context of climate change, it is important to determine a rational way by which forest plantations will create the maximum possible productivity in the shortest period of time [7].

The efficiency of forest restoration and their productivity in the future depends on the quality of planting material of forest-forming species. Today, about 80 % of forests are artificially created, and therefore foresters and scientists face the issue of production of high-quality planting material, including the common species - Scots pine. Reproduction of forests with the help of high-quality planting material is the basis for a high survival rate, intensive growth and development, good competitiveness of planting material with shrubs and herbaceous vegetation [53].

Of great importance in the creation of high-quality planting material is the use of seeds collected on permanent forest seed bases. The quality of seeds directly affects the productivity of forests in the future. According to the results of genetic testing of selected seeds from 50 % of the best trees, the selection effect of forest seed plantations increases [34, 46]. Seeds collected from forest seed plantations have better seed quality (15–20 %) larger, germination energy and germination) than seeds obtained from normal plantations. For example, the weight of seeds is 10–15 % greater in seeds grown in clonal seed plantations than in conventional forests [27]. Numerous studies also show that the quality indicators of Scots pine seeds (size, germination energy, germination, etc.) are affected by the geographical origin and climatic conditions of growth. For example, seeds collected in the northern regions have higher seed viability, seeds in the western regions lose their germination faster [46].

Also, during the cultivation of planting material, great attention is paid to fertilization, the use of means of protection against weeds, pests, diseases, and the use of auxiliary substances (growth stimulants and microfertilizers) that help plants adapt to adverse conditions of growth and development (drought, frost, etc.) [30, 33]. Scots pine plantations can be restored in three ways: planting, direct seeding, and natural regeneration. In most forestry models, planting material is the most common method. Direct seeding is an old reforestation method that is now rarely used. In Poland in the 1960s and 1970s, 5.3–7.8 percent of clearcuts were restored in this way, compared to 2.6 percent in the 1980s. This method has many advantages. First, reforestation costs are lower than planting costs. Second, direct seeding mimics natural regeneration. Thirdly, forest plantations formed in this way, growing in high density, are characterized by high quality wood. The main reason why direct seeding is now so rare is the risk of failed regeneration due to greater exposure to biotic and abiotic stress factors on the germinating seed than on the established plant. Comparative studies show that when restored by direct seeding or self-seeding, Scots pine and other tree species grow more slowly and have less chance of survival than planted seedlings [12].

Planting of forest crops has some advantages compared to sowing, for example, reduction of seed consumption, uniform placement of seedlings on the area, seedlings are less suppressed by weeds and shrubs, the number of maintenance operations is reduced, etc. [28]. The disadvantages of planting seedlings include their lower resistance to diseases, pests, environmental conditions and frequent damage to the main root, which is intensively formed in the first years [31].

Recently, forest plantations in Ukraine have been restored mainly artificially, and the main type of planting material is usually seedlings. Of particular importance is the creation of highly productive and sustainable forest plantations of the most common forest-forming species, i.e. Scots pine, close to natural stands. This can be achieved precisely with the help of sowing seeds. This method is close to the conditions of natural renewal of pine forests [53].

The use of planting material with a closed root system, as well as with an open root system, has a long history. Scientific works of 1725 have references to the literature that contains information about planting tree plants with a lump of earth, and during the 20th century, there were also methods of planting saplings with a lump of earth during forestry work. They were harvested on well-restored cuttings that are more than 5 years old.

The use of seedlings grown by the closed root system method is the most common method of forest regeneration in many countries, because a good condition of the root system determines the quality of the seedlings used for regeneration, and is also a necessary condition for their successful use in the forest. Outdoors, roots are considered susceptible to overwintering damage, especially if there is no protective snow cover, which impairs seedling quality [40]. And therefore, maintaining the integrity of the root system, which is responsible for the absorption of nutrients and water, during the planting of seedlings is the key that is paid attention to when choosing a method of creating planting material.

The issue of afforestation of areas damaged by forest fires, which arise as a result of climate change, is gaining relevance. These areas have significant or complete loss of forest vegetation and layers of forest litter, which in turn complicates the natural regeneration of Scots pine. Afforestation of such areas with planting material with an open root system is inefficient and is not characterized by survival or death of forest crops [38].

Therefore, as mentioned earlier, the advantages of growing planting material with a closed root system have been repeatedly proven by various scientists, because this approach involves transplanting 1-3 year-old seedlings, which is not traumatic for the plant, effective regulation of nutrition and moisture conditions, effective control of pests of root systems and diseases, obtaining several rotations of planting material suitable for creating forest crops during one growing season, etc. In addition, the issue of further growth and development of planting material in forest crops is not sufficiently studied. One of the disadvantages of creating planting material with a closed root system is its higher cost (by 40 %) compared to seedlings with an open root system [41].

Two methods of growing planting material with a closed root system are common: when seedlings from open ground are moved and pressed into the substrate and in containers. The most popular of these methods is the use of containers made of various materials (paper, plastic, special fabric, etc. that can be placed directly on the landing site). Containers for growing seedlings come in many shapes, sizes and are made from different materials such as polystyrene, polyethylene, rooting agents, fiber or paper. It is convenient to transport the seedlings to the places of silvicultural works, they are used as a shell to give shape to the coma in which the substrate remains, which improves the adaptation of the seedlings and contributes to the mechanization of these works. The primary function of any container is to hold a discrete supply of growing medium, which in turn supplies water, air, mineral nutrients, and physical support for the planting material [50].

The most common container for growing seedlings is black plastic trays. It has been established that the black color absorbs solar radiation and increases the temperature of the substrate. An ideal nursery container should have structural strength and good insulation, the material should not be brittle or decompose quickly, be strong during handling and transportation, and promote a healthy root system. In addition, the container should be light in weight, provide good drainage, be durable and accessible, not pose a danger to customers during planting and ease of disposal (sustainability) of the product. The type of container can significantly affect the root morphology of container-grown plants [10].

The question of selecting the type of substrate, using mineral fertilizers and auxiliary substances, and methods of growing seedlings with a closed root system remains relevant.

Optimal conditions for the growth and development of plants are determined by a whole set of factors, including the reaction of the environment. Scientific studies and practical experience have established that high values of environmental reaction parameters (acidity and alkalinity) negatively affect the growth of root and stem parts of plants. The development of the direction of growing planting material in container seedlings 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 into the characteristics of growing planting material in in individual and multi-chamber containers of various types and sizes, work on industrial cultivation has begun. Today, many types of insulating materials are known: peat and ceramic pots, briquettes, paper honeycombs, polyethylene bags and others [19, 42].

The substrate must meet the following requirements: be light in weight to facilitate transportation to the landing site; firmly hold cuttings or seedlings in place; maintain a sufficient amount of moisture to avoid the need for frequent watering; be porous enough to allow excess water to drain easily; ensure sufficient root aeration; do not contain seeds, nematodes and diseases; undergo sterilization without changing their properties; have enough nutrients for healthy initial plant development; have enough nutrients for healthy initial plant development; not have a high level of salinity; have an appropriate pH level; be stable, do not swell, do not shrink excessively and do not crust over in the sun;

The growth of seedlings in seedling containers is mainly influenced by the air and water properties of the substrate, as well as its chemical composition.

For the production of seedlings in containers, peat with a high content of sphagnum is used, which has such favorable characteristics as high porosity, moistureholding capacity, sterility and low mineral content. These properties facilitate regulation of fertilizer application rates and properties (such as low pH, high cation exchange capacity, low natural fertility, proper balance of aeration and water-retaining porosity) and provide reasonable growing conditions in protected soil conditions. However, modification of inadequate physical parameters of the substrate is difficult, especially with too low or too high levels of air capacity, which can be explained by compaction of the substrate [26].

Sand is a common substrate for germinating seeds. Before use, it is sieved to remove small silt particles that lead to the formation of a crust on the surface. For a better result, you can use sand with a size of 0.5–1 mm for germinating seeds and 1–2 mm for rooting cuttings. Sand from a sea beach can contain a high salt content, which must be washed before use. Fine gravel (5 mm) is successfully used for rooting cuttings and as an additive to the soil mixture. Both sand and gravel are heavy (bulk weight 1000–1700 g/l) and make it difficult to transport seedlings to the field. Sand, especially fine sand, should never be used as a potting soil additive because it clogs the pores [49].

The bark of coniferous and deciduous trees is a good alternative to peat with almost the same properties. Bark is a cheap byproduct of many sawmills. It can be used from coniferous (cedar, pine, fir) or deciduous trees; it is also recommended to use the bark of tree ferns. There is only limited information on the suitability of tropical tree species. The bark should be ground with a hammer through a sieve with 2–3 cm holes and then composted for 4-6 months, as fresh bark may contain tannins, phenols, resins or terpenes that are toxic to plants if not broken down. Higher composting temperatures also help reduce insect and pathogen levels. If the bark is not fully composted, plants grown in this environment may suffer from a nitrogen deficiency, as composting bacteria need nitrogen to break down organic matter [36].

Perlite is a siliceous material of volcanic origin, extracted from lava flows. Raw ore is crushed and heated to a temperature of about 760 °C, causing the water contained in it to evaporate and expand the particles like a sponge. It is very light (80–100 g/l), can hold 3–4 times its own weight in water, has an almost neutral pH, and does not contain mineral nutrients. Most useful for increasing aeration in the mixture and in combination with peat moss is a very popular substrate for cuttings in the USA [35].

As additional materials for substrates can also be used: coconut husk, rice husk, sugarcane pulp, coffee husk, old sawdust and other waste can be used similarly to the materials listed above. New materials will undoubtedly be found through ongoing research. Most soilless substrates can be used alone or added to soil to improve its properties.

The analysis of literary sources shows the successful use of substrates from pine trees for growing crops in greenhouses and nurseries, which have caused considerable interest among manufacturers and producers of substrates. Pine tree substrates can be made from pine trees that have been chipped and shredded (with or without bark, limbs, needles, etc.) in a hammer mill or from pure wood shavings (≈40 % pine wood, 50 % bark and 10 % needles) , which is produced from the by-products of the process of harvesting pine trees [3, 8].

Another method that is gaining popularity is growing plants without soil. Cultivation of plants without soil is any method of growing plants without using soil as a medium for rooting [6]. This relatively simple definition covers a variety of plant growth systems, which typically involve the containerization of plant roots in a porous rooting medium known as a "substrate" or "growing medium." Compared to soil cultivation, soilless production can be more cost-effective, providing higher yields and faster harvesting from smaller areas of land. Soilless systems are also generally higher water and nutrient use efficiency. As a result, over the past 50 years, they have become increasingly important worldwide [9].

Warmer and drier conditions associated with climate change are accelerating forest mortality worldwide [22]. In Europe, the frequency and intensity of droughts have increased over the past 30 years [23]. Particularly recent consecutive droughts in 2015–2019 caused large-scale tree deaths in Central European forests [4]. Due to ongoing climate change and accumulation of stress conditions, drought-induced forest loss is expected to increase in many regions [21].

But not only increased drought has a significant impact on forests. Higher temperatures, increased nitrogen deposition in the atmosphere and increased CO_2 concentrations are changing the functioning of forest ecosystems, mainly affecting the productivity and growth of the forest [16].

One of the aids in growing planting material is the use of growth regulators. Plant growth regulators are organic chemical compounds that alter or significantly regulate various physiological processes in a plant when applied in low concentrations. These plant growth regulators have become an integral component of agrotechnical measures for most plants. Research by N. V. Puzrina and G. O. Boyko prove that the use of growth regulators for pre-sowing seed treatment is a good means of increasing the morphometric parameters of woody plants. The use of such growth regulators as trichodermin, nematophagin, fumar, emistim contributed to the increase in the height of one-year-old pine seedlings of the usual seedling height (by 3–14 %), root neck diameter (6–26 %) and root length (by 3–9 %) [44].

In order to prevent the roots from drying out during forestry work (transplantation, storage, transportation of planting material), there are polymer compounds that create a film coating (for example, Akvasorb-3005 KM and Teravet-100). These substances, due to the protection of the roots, are able to increase the percentage of survival of the planting material. Also, these drugs can be used for introduction into the landing gap, which leads to an increase in costs, which is economically unprofitable [43].

The use of mycorrhiza in seedling forest crops is also relevant. Scots pine is an obligate mycotrophic species, that is, its root system can be in symbiosis with fungi. Fungal hyphae penetrate the soil and envelop the roots of a woody plant, increasing their absorption capacity and contributing to the supply of available nutrient compounds (nitrogen, phosphorus and potassium) to the plant, thus increasing the percentage of survival of the planting material [51].

One of the measures to improve the sowing qualities of seeds of woody plants is the use of trace elements for seed treatment. Also, Preparations based on microelements may contain other auxiliary substances in their composition: humic acids, amino acids, macroelements and phytohormones. Although these drugs are more widely used in crops of widely used crops, they are also used in forestry. Thanks to this composition, preparations based on microelements not only provide plants with nutrients, but are also able to increase the resistance of plants to abiotic factors (diseases, pests, effects of high temperatures, late frosts, etc.) [48].

Materials and Methods.

The research was conducted in the conditions of the Northern Forestry Office of the State Enterprise "Forests of Ukraine", which unites the forests of Sumy Oblast and Chernihiv Oblast.

It was organized in 1936 on the basis of the forests of the Ivolzhan, Nikol, Yunakiv, Myropil, Veliko-Vystorop, Lebedyn and Mezhyrich forests, with a total area of 41,000 hectares. The current forest management is carried out according to the 1st category in accordance with the requirements of the current forest management instructions, the decisions of the first forest management meeting and the technical meeting based on the results of field work.

According to forest vegetation zoning, the territory of the forest farm belongs to the zone of the Left Bank forest-steppe. According to the forest typological zoning of Ukraine (according to D. Vorobyov), the territory of the forest farm belongs to the forest typological district of the Dnipro fresh maple-linden thickets [26]. The climate of the area where the forest farm is located is moderate-continental. It is characterized by an optimal amount of precipitation, sufficient for the main forest-forming species.

Of the climatic factors that negatively affect the growth and development of forest plantations, there are late spring and early autumn frosts, strong dry winds. The territory of the forest farm belongs to lowland forests by the nature of the terrain. Its eastern part is strongly cut by valleys of small rivers, streams, ravines and streams. There is a significant variation in altitude above sea level (115-230 m). Along the Psel River there is a floodplain terrace with a width of several hundred meters to several kilometers, which is characterized by specific properties of the soil-forming process.

From the point of view of soil richness, as well as the nature of the soil formation process, the following types of soil are distinguished on the territory of the forest farm:

1. Gray forest (dark gray, gray and light gray).
2. Sod-podzolic soils:
3. Marsh soils:

The main forest types, which are characterized by the richness of the soil and forestry D_2KLD – 67 %; C_2LDS – 17 %; C_3LDS – 4 %; B_2DS – 4 %.

The economic activity of the forest farm is aimed at growing highly productive sustainable plantations, processing wood, and creating conditions for recreation. Forestry occupies a significant place in the economy of the district. The main directions of its development are obtaining marketable wood, while preserving the protective properties of the forest, recreational purposes, as well as protection and reproduction of hunting fauna.

Agricultural land available in the forest fund is used for the needs of forestry workers and feeding of hunting fauna. The value of forest haymakers in the fodder balance of the district is insignificant.

90 % of the felling of the main use was carried out in places designed by forest management. In connection with the change of felling, forest management was additionally included areas for felling of the main use. Now and at the time of the basic forest management in 2007, the forest farm had an approved cut – 22.7 thousand cubic meters of liquid. The yield of commercial wood corresponds to the design.

During felling of the main use, no loss of wood was detected.

In general, main-use fellings improved the state of the forest and exploitation fund, thanks to the revision of the estimated felling of common ash, overgrown plantations, which were already losing their protective functions and the marketability of wood, were included in the felling.

The state of plantations not covered by maintenance fellings is satisfactory for forest management. Accounting for species care felling in the forest farm is generally satisfactory. The quality of maintenance felling and selective sanitary felling is satisfactory. Wood residues were not allowed in the felling areas. The main method of felling maintenance is combined, which combines the principles of bottom and top maintenance.

Wood from care and sanitary felling is sold in round form, and 30 % is used for own needs, including processing – 21 %. The research was carried out in the nursery and forest crops of the Pishchan Forestry. Pishchan Forestry is part of the "Sumy LG" branch of the State Enterprise "Forests of Ukraine" and is located in the forest-steppe zone of Ukraine. Forestry has an area of 8,049.5 hectares and is territorially located in the Sumy district (6,714.0 hectares), Bilopolsky district (217,0 hectares) and the city of Sumy (1,118.5 hectares). It consists of 3 workshops, which in turn are divided into 12 rounds. 16 people work in forestry: a forester, a forester's assistant, 2 logging foremen, 9 foresters, an accountant, 2 tractor drivers.

According to forest vegetation zoning, the territory of forestry belongs to the zone of Livoberezhno-Dnipro Forest Steppe. According to the forest typological zoning of Ukraine (D. V. Vorobyov – 1952), the forestry territory belongs to the forest typological district of the Dnipro fresh maple-linden thickets. According to the forestry zoning of Ukraine (S. A. Gensiruk – 1992), the forestry territory belongs to the northern Poltava plain with oak, linden-maple-oak forests and meadow steppes. The climate of the forestry area is temperate-continental, which is characterized by the amount of precipitation sufficient for the main forest-forming species. A brief description of climatic conditions that are important for forestry is given in the table.

Of the climatic factors that negatively affect the growth and development of forest plantations, there are late spring and early autumn frosts, strong dry winds.

The territory of forestry, according to the nature of the relief, belongs to plain forests. Its eastern part is heavily incised by valleys of small rivers, streams, ravines and gullies with significant variations in altitude above sea level (115–230 m). Along the Psel River there is a floodplain with a width of several hundred meters to several kilometers, which is characterized by specific properties of the soil-forming process.

The western part is a large flat area and only small areas of ravines and streams. The main climatic indicators of the forest farm area are given in the table 1. The main types and types of soils: gray forest (dark gray, gray and light gray), turf-podzolic, turf-podzolic gley, swamp (peat-gley and peat). The main types of forest: D_2KlD – 65,2 %, C_2LDS – 17 %, C_3LDS – 3,6 %, B_2DS – 3,8 %.

Erosion processes in the territory of forestry are poorly developed. In forests, water erosion is hardly noticeable due to the significant moisture content of forest soils and the soil-protective capacity of tree stands. There is no wind erosion. In small forest tracts growing on the slopes of streams, water erosion is more severe, which is facilitated by rains and surface runoff.

According to the degree of moisture, most of the soils are fresh. Forest areas with excessive moisture account for 1,8 % of the area covered by forest vegetation.

In the Pishchan Forestry, today the area of forest crops is 242,8 hectares, of which 35,8 hectares were created this year. Of this total number of forest crops, only 18,1 ha are for conifers (5,8 ha for 2-year, 3-year-old crops), the rest of crops with the main species being oak.

There are 2 forest nurseries with a total area of 1,9 hectares on the territory. Today, oak is grown for its own needs (150,000 pieces of 1-year-old oak are available). This year, 3,050 kg of acorns were collected, of which 1,950 kg were transferred to other branches of the branch, 630 kg were sown in autumn to create forest crops by sowing, and the rest were sown in the nursery for further cultivation of planting material.

Table 1. Climatic indicators.

Name of indicators	Unit of measurement	Value	Date
1	2	3	4
1. Air temperature:			
- average year	degree	+6.0	
- absolute maximum	degree	+31.0	
- absolute minimum	degree	-27.0	
2. Amount of precipitation per year	mm	508	
3. Duration of the growing season	days	197	
4. Late spring frosts			02.06
5. The first autumn frosts			11.09
6. The average date of freezing is a year			16.12
7. Average date of flood onset			24.03
8. Snow cover:			
- thickness	see	12	
- appearance time			12.12
- climbing time in the forest			21.03
9. Depth of freezinggrunt	see	49	

Table 1. Continuation.

10. Direction of prevailing winds by seasons:			
- winter	point	West	
- spring	point	South West	
- summer	point	South West	
- autumn	point	North West	
11. Average speed of prevailing winds by season:			
- winter	m/sec.	5.2	
- spring	m/sec.	4.4	
- summer	m/sec.	3.2	
- autumn	m/sec.	4.2	
12. Relative air humidity	%	6.8	

Spruce nurseries were created for their further sale as planting material and as Christmas trees (available with a height of 0,25–1 m – 500 pcs., up to 0,25–0,5 m – 800 pcs., up to 0,25 m – 1300 pcs.). The purpose of research is the study of the technology of growing the planting material of Scots pine seedlings and determining the features of their growth and development (adaptation) depending on the methods of obtaining and the type of substrate.

Object of study – Scots pine seedlings, the technology of obtaining planting material and its adaptation.

Subject of study – growth and development of Scots pine seedlings with an open and closed root system, type of substrate.

To solve the set goal, we conducted 2 experiments and set the following tasks: to investigate the influence of the substrate on the germination of Scots pine seeds; to determine the viability of Scots pine seedlings (seedlings) depending on the methods of obtaining planting material and the type of substrate (open and closed root system); to establish biometric indicators of Scots pine seedlings (seedlings) depending on the method of obtaining planting material and the type of substrate (height of tree plants, growth height, diameter).

Method conducting research involved the following measurements: Soil similarity was determined according to GSC (ISO 13056.7-93). Height measurements were made with a measuring ruler. The diameter of the root neck is measured with a compass. The mass of raw seedlings was determined on a scale with an accuracy of 0.001 g. Statistical data processing with the Statictica 9.0 program.

Results. Experiment 1. Peculiarities of adaptation of Pinus sylvestris seedlings depending on the method of obtaining.

One of the most important indicators of seed suitability for sowing and determination of its weight norm is seed germination. This indicator is directly related to the growth and development of plants and their future productivity [47].

In the course of the study of the germination of Scots pine seeds (Table 2), it was established that the seeds with the use of "Jiffy" peat tablets had the highest germination – 81,6 %.

Table 2. Similarity of Scots pine seeds depending on the type of substrate, %.

Research option	Similarity, %	Difference compared to control, %
Soil	73,8	–
Peat tablets "Jiffy"	81,6	10,6
Soil + Peat tablets "Jiffy"	75,5	2,3

Seeds sown in a mixture of soil and peat tablets "Jiffy" were characterized by slightly lower germination – 75,5 %.

The lowest similarity was recorded for soil use – 73,8 %. The difference compared to the control (soil) was 10,6 % for substrate based on Jiffy peat tablets, 2.3% for soil and Jiffy peat tablets.

The survival rate of the planting material is a crucial aspect for the productivity of the forest plantations in the future. One of the main parameters that directly affect grafting is the share of root system preservation [52]. Research by scientists has proven that planting material with a closed root system is the least traumatic when planting, due to which it has high survival rates [40].

According to the results of our research (Table 3), it was found that planting material with a closed root system has a higher percentage of survival (76,2–82,3 %) compared to the control variants (seedlings with an open root system) – 60,2 %. Comparing the percentage of survival of planting material depending on the substrate used, it should be noted that seedlings grown on a mixture of soil and peat tablets "Jiffy" have the highest survival rates – 82,3 %, which is 36,7 % more compared to the control. The variants grown using a soil-based substrate were characterized by a slightly lower percentage of survival – 76,2 %, which is 26,8 % more compared to the control.

Table 3. Survival of planting material with a closed and open root system depending on the type of substrate, %.

Research option	Survival rate, %	Difference compared to control, %
Seedlings with an open root system (control)	60,2	–
Seedlings with a closed root system (soil)	76,2	26,8
Seedlings with a closed root system (soil + Jiffy peat tablets)	82,3	36,7

The height of woody plants plays an important role in their survival and competitiveness, especially in dense stands. First of all, this competition concerns light, the lack of which causes plants to stop growing or die. Also, a developed plant trunk is able to better transport nutrients and water absorbed by the root system to other plant organs, which also affects the productivity of plantations in the future.

It was found that the method of obtaining planting material and the type of substrate had a significant effect on the height of one-year-old Scots pine seedlings (Table 4). The smallest height parameters were formed by seedlings with an open root system (control) – 18,7 cm. The highest seedlings were formed by the method of obtaining planting material with a closed root system: on a soil substrate – 24,3 cm; on a substrate made of a mixture of soil and peat tablets "Jiffy" – 23,3 cm, which is 24,6 %, which is 29,9 and 24,6 % higher, respectively, than the control variant. The Duncan test for plant height was equal to 2,5 cm.

The growth of plants in height characterizes the value of the tax indicator and the intensity of growth and development of forest plantations over a certain period of time. This indicator, like the height, to some extent reflects the expediency of carrying out this or that measure during the cultivation of forest plantations.

Table 4. Height of 1-year planting material with a closed and open root system depending on the type of substrate, cm.

Research option	Height, see	Difference compared to control, %
Seedlings with an open root system (control)	18,7	–
Seedlings with a closed root system (soil)	24,3	29,9
Seedlings with a closed root system (soil + Jiffy peat tablets)	23,3	24,6
Duncan test	***2,5***	

The research data obtained by us in 2023 (Table 5) indicate a positive influence of the method of obtaining the Scots pine planting material and the type of substrate (Duncan test = 1,6 cm). The smallest increase in height of one-year-old Scots pine plants was formed by the method of obtaining planting material with an open root system – 10,9 cm. The largest increase was recorded on planting material with a closed root system: on a substrate made of a mixture of soil and peat tablets "Jiffy" – 14,4 cm; on a soil substrate – 15,5 cm, which is 32,1–42,2 % more compared to the parameters of seedlings with an open root system.

Table 5. Growth in height of 1-year-old planting material with a closed and open root system depending on the type of substrate, cm.

Research option	Growth in height, see	Difference compared to control, %
Seedlings with an open root system (control)	10,9	–
Seedlings with a closed root system (soil)	15,5	42,2
Seedlings with a closed root system (soil + Jiffy peat tablets)	14,4	32,1
Duncan test	***1,6***	

The diameter of the stem is the most common indicator used to estimate the thickness of the trunk, which changes dynamically even at the age of one year.

According to the results of research in 2022 (Table 6), it was established that the largest diameter of the root neck in one-year-old Scots pine plants was formed using planting material with a closed root system with a soil-based substrate – 5,06 mm.

The variants of planting material with a closed root system based on soil and peat tablets "Jiffy" had a slightly smaller diameter – 5,02 mm. The smallest diameter values were recorded on the control variants (seedlings with an open root system) – 4,82 mm. The difference between variants with a closed root system under different types of substrates compared to the control was 4,14–4,97 %. Duncan test – 0,11 mm.

Table 6. Diameter of 1-year planting material with closed and open root system depending on the type of substrate, mm.

Research option	Diameter, mm	Difference compared to control, %
Seedlings with an open root system (control)	4,82	–
Seedlings with a closed root system (soil)	5,06	4,97
Seedlings with a closed root system (soil + Jiffy peat tablets)	5,02	4,14
Duncan test	***0,11***	

Experiment 2. Obtaining and adaptation of Pinus sylvestris planting material depending on age.

According to the results of research carried out in 2022 (Table 7), it was shown that the 1-year and 3-year planting material of Scots pine with a closed root system (with a closed root system) was characterized by better survival compared to planting material with an open root system (with an open root system). One-year-old seedlings with a closed root system had a survival rate of 73,9 %, which is 7 % more than seedlings with an open root system (66,9 %). Three-year-old planting material with a closed root system also had higher survival rates (67,7%), which is 10 % higher than seedlings with an open root system (57,7 %).

Seedlings from with an open root system were characterized by a higher percentage of the death of woody plants within three years after planting.

Table 7. Survival of Scots pine in forest cultures created by planting material with closed and open root systems.

Age of forest crops	Survival rate (%) of planting material with a root system		Difference compared to control, %
	closed	open (to)	
1-year-old	73,9	66,9	10,5
3 years old	67,7	57,7	17,3

Thus, the percentage of survival in seedlings with an open root system decreased by 9,4 % (comparing 1- and 3-year-old planting material), and in seedlings with a closed root system – by 6,2 %, which may indicate a better adaptation of planting material with a closed root system to soil conditions including due to the remaining nutrients from the soil mixture used as a substrate during their cultivation.

The height of plants is an important indicator that indicates the expediency of using this or that measure in growing technology. Light competition is crucial for the survival, growth and reproduction of individuals in dense stands.

The height of 1-year planting material from with a closed root system (Table 8) was 20,2 cm, which is 6,5 cm more compared to planting material with an open root system (13,7 cm). The height of 3-year-old seedlings was also characterized by higher values in planting material with a closed root system – 71,3 cm, which is 16,3 cm higher than in seedlings with an open root system (55,0 cm). The difference compared to the control (seedlings with an open root system) at 1-year age was 47,4 % and at 3-year age – 29,6 %.

Table 8. Scots pine height in forest cultures created by planting material with closed and open root systems.

Age of forest crops	Height (cm) of planting material with a root system		Difference compared to control, %	Duncan test
	closed	open (to)		
1-year-old	20,2	13,7	47,4	6,5
3 years old	71,3	55,0	29,6	14,8

Growth in height, like the height of the plant itself, is of great importance in the development of forest plantations. This indicator characterizes the intensity of growth of woody plants and reflects the impact of certain agrotechnical measures.

According to the results of the analysis of growth indicators by the height of Scots pine seedlings (Table 9), it was established that the largest growth of 1-year-old plants was formed from with a closed root system – 9,2 cm, which is 2,6 cm more compared to planting material with an open root system.

The same trend was observed in 3-year-old plants: growth in height in planting material with a closed root system was 30,2 cm, which is 5 cm more compared to planting material with an open root system. The difference in height growth compared to the control (seedlings with an open root system) at 1-year age was 39,4 % and at 3-year age – 19,8 %.

Stem diameter is one of the most common measurements taken to assess the growth of woody vegetation and the commercial and environmental benefits it provides (e.g. wood or biomass products, carbon sequestration, landscape reclamation).

Table 9. Height growth of Scots pine in forest cultures created by planting material with closed and open root systems.

Age of forest crops	Seedling height growth (cm) of planting material with a root system		Difference compared to control, %	Duncan test
	closed	open		
1-year-old	9,2	6,6	39,4	2,5
3 years old	30,2	25,2	19,8	4,7

According to the results of the research conducted in 2023 (Table 10), it was established that the 1-year-old and 3-year-old planting material grown with a closed root system – 7,67 and 13,15 mm, respectively, which is 1,55–1,79 mm more compared to planting material with an open root system (6,12 and 11,36 mm, respectively).

Table 10. The diameter of the root neck of Scots pine in forest cultures created by planting material with a closed and open root system.

Age of forest crops	Seedling diameter (mm) of planting material with a root system		Difference compared to control, %	Duncan test
	closed	open		
1-year-old	7,67	6,12	25,3	1,5
3 years old	13,15	11,36	15,7	2,1

The difference in the diameter of the root neck of Scots pine compared to the control (seedlings from with an open root system) at the age of 1 year was 25,3 % and at the age of 3 – 15,7%. According to the results of variance analysis, the difference is not significant (Duncan test 1,5 and 2,1 mm), respectively.

CONCLUSIONS. Based on the results of our research in 2023, we can draw the following conclusions for **experiment 1:**

1. The highest seed germination was achieved using "Jiffy" peat tablets - 81.6%. Seeds sown in a mixture of soil and peat tablets "Jiffy" were characterized by slightly lower germination – 75,5 %. The lowest similarity was recorded for soil use – 73,8 %.
2. Seedlings with a closed root system grown on a mixture of soil and peat tablets "Jiffy" have the highest survival rate – 82,3 %, which is 36,7 % more compared to seedlings with an open root system (control) – 60,2 %. The variants grown using a soil-based substrate were characterized by a slightly lower percentage of survival – 76,2 %, which is 26,8 % more compared to the control.
3. The tallest seedlings were formed by the method of obtaining planting material with a closed root system: on a soil substrate – 24,3 cm; on a substrate made of a mixture of soil and peat tablets "Jiffy" – 23,3 cm, which is 24,6 %, which is 29,9 and 24,6 % higher, respectively, than the control variant (18,1 cm).
4. The smallest height parameters were formed by seedlings with an open root system (control) – 18.7 cm. The highest seedlings were formed by the method of obtaining planting material with a closed root system: on a soil substrate – 24,3 cm; on a substrate made of a mixture of soil and peat tablets "Jiffy" – 23,3 cm, which is 24,6 %, which is 29,9 and 24,6 % higher, respectively, than the control variant.
5. The smallest increase in height of one-year-old Scots pine plants was formed by the method of obtaining planting material with an open root system – 10,9 cm. The largest increase was recorded on planting material with a closed root system: on a substrate made of a mixture of soil and peat tablets "Jiffy" – 14,4 cm; on a soil substrate – 15,5 cm, which is 32,1–42,2 % more compared to the parameters of seedlings with an open root system.
6. The largest root neck diameter in one-year Scots pine plants was formed using planting material with a closed root system with a soil-based substrate – 5,06 mm. The variants of planting material with a closed root system based on soil and peat tablets "Jiffy" had a slightly smaller diameter – 5,02 mm. The smallest diameter values were recorded on the control variants (seedlings with an open root system) – 4,82 mm.

Conclusions for experiment 2:

1. 1-year-old and 3-year-old pine seedlings with a closed root system were characterized by better survival compared to seedlings with an open root system. One-year seedlings with a closed root system had a survival rate of 73,9 %, which is 7 % more compared to seedlings with an open root system (66,9 %). Three-year-old planting material with a closed root system also had higher survival rates (67.7 %), which is 10 % higher compared to seedlings with an open root system (57,7 %).
2. Scots pine seedlings grown with a closed root system were taller than seedlings with an open root system. Average in quality of 1-year-old planting material from with a closed root system was 20,2 cm, which is 6,5 cm more compared to planting material with an open root system (13,7 cm). The height of 3-year-old

seedlings was also characterized by higher values in planting material with a closed root system – 71,3 cm, which is 16,3 cm higher than in seedlings with an open root system (55,0 cm). The difference compared to the control (seedlings with an open root system) at 1-year age was 47,4 % and at 3-year age – 29,6 %.

3. It was established that the largest increase was formed by 1-year-old plants with a closed root system – 9,2 cm, which is 2,6 cm more compared to planting material with an open root system. The same trend was observed in 3-year-old plants: the increase in height in planting material with a closed root system was 30,2 cm, which is 5 cm more compared to planting material with an open root system. The difference in height growth compared to the control (seedlings with an open root system) at 1-year age was 39,4 % and at 3-year age – 19,8 %.

4. The 1-year-old and 3-year-old planting material grown from with a closed root system – 7,67 and 13,15 mm, respectively, which is 1,55–1,79 mm more compared to planting material with an open root system (6,12 and 11,36 mm, respectively). The difference in the diameter of the root neck of Scots pine compared to the control (seedlings with an open root system) was 25,3 % at the age of 1 year and 15,7 % at the age of 3 years. According to the results of variance analysis, the difference is not significant (Duncan test 1,5 and 2,1 mm, respectively).

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