CONDITION AND METHODS OF REPRODUCTION OF THE *QUERCUS ROBUR* L. POPULATION IN THE CONDITIONS OF THE LEFT-BANK FOREST-STEP OF UKRAINE

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INTRODUCTION

Morphology, biological features and economic importance of common oak (*Quercus robur L.)*

The forests of Ukraine are the most powerful factor that stabilizes the functional organization of natural ecosystems at a certain level, increases their resistance to anthropogenic disturbance and climate change [82]. Ukraine is one of the countries with a relatively low average forest cover, as only 16.7 % (9.9 million hectares) of the territory is covered by forests. Ukraine ranks only ninth in Europe in terms of forest cover [84]. Common oak (*Quercus robur* L.) grows in 28 % of Ukraine's forests [83].

Oak is one of the most economically important hardwood tree species in Europe, and according to forecast models, its prevalence will increase due to progressive global climate change. With the increasing demand for wood and the need to balance carbon emissions and carbon sequestration, it is crucial to address the issue of afforestation of agricultural land [68, 85].

It is a perennial, deciduous, broad-leaved tree of the Beech family (*Fagaceae*), characterized by considerable durability and strong wood. This tree species is one of the most widespread in Europe, its distribution area extends from Scandinavia and the Baltic countries in the north to the Iberian Peninsula, Italy and the Balkans in the south, and also covers part of Western Asia. The common oak grows in both plain and low-mountain areas, forming mixed and pure stands, especially in temperate climates.

In addition to its important ecological significance, the oak tree plays a significant role in the culture and traditions of many European nations. Its strength, durability and beauty have long been associated with strength, wisdom and invincibility. Oak leaves, acorns and the shape of the tree itself are often used in heraldry, symbols of state institutions, coins, as well as in folk art. In many European countries, the oak tree is a national or regional symbol, and in some – even an object of special environmental protection status.

Oaks are one of the most common tree species in the world. Throughout history, oaks have provided shelter and food for people and wildlife. Growing oaks in appropriate areas in Ukraine can provide landowners with protection from soil erosion, wildlife habitat, and timber. Oaks also absorb carbon dioxide and release oxygen. This process maintains the atmospheric balance that is so often discussed in conversations about global climate change. Farkas and Saniga [22] argue that with the increasing frequency of disasters and extreme climatic conditions, the cultivation of oak, which acts as a stabilizer of forest ecosystems, is becoming increasingly important [33, 59].

There are 23 species of oak in Ukraine, but most of them are not widely distributed. The largest areas are occupied by scotch oak, red oak and common oak. Common oak is considered the most durable tree species in Ukraine, it is one of the most valuable species used in the forestry industry. In Ukraine, common oak plantations occupy about 1,621 thousand hectares (96 % of the total area of oak forests). Oak wood in the country is used in the manufacture of furniture, because it has a high degree of strength and attractive appearance. Due to the high content of tannins in the wood, oak is considered the most resistant to decay of all hardwoods.

Due to its grandeur, durability and decorative qualities, it is widely used in landscaping cities, parks, forest parks and private gardens. Oak massifs and groves are popular in landscape design. The common oak has a dense, wide crown with large, carved leaves, which in autumn acquire a golden or reddish color. It looks spectacular both in single plantings and in group compositions. The common oak can live for several centuries, becoming a real decoration of the landscape and a place of rest for many generations. This species is relatively resistant to air pollution, drought and frost, which makes it suitable for growing in urban conditions. It is an important element of the ecosystem, providing shelter for many species of animals and insects. The common oak emits phytoncides that have an antimicrobial effect and help purify the air.

There are various options for using common oak in landscaping, for example, solitary plantings, this is a solitary tree and it will become the center of the composition and the dominant of the landscape. Alley plantings of this species are great for creating alleys along paths, in parks and squares. As for group plantings, oaks can create the impression of a natural forest and provide shade in hot weather. It can be used to form high and dense hedges that will protect the site from the wind and prying eyes. Another important type of use is the creation of forest reclamation areas, pedunculate oak is used to restore forests, protect soils from erosion and create field buffer strips.

In general, oak is a ring-porous species that has a high proportion of heartwood [69] with high economic potential. A characteristic feature of oak heartwood is its high moisture content, similar to sapwood [36]. Oak provides valuable wood with high density, strength and durability [65]. Oaks have high drought tolerance and a wide ecological amplitude compared to other native tree species. In a world of progressive climate change, tree species with high drought tolerance are becoming increasingly important, especially in Central Europe [63, 80]. Given this, oaks can contribute to timber production during prolonged drought stress. In addition, oak is relatively resistant to biotic factors (e.g. insects and pathogens) compared to other tree species. Oaks can positively influence the growth of mixed tree species and demonstrate high ecological value for species diversity [52, 63].

Oak wood is characterized by high hardness, strength and durability, which makes it one of the most valuable species for use in various industries. Due to its physical and mechanical properties, it has been highly valued for centuries in construction, furniture, shipbuilding and carpentry. Its dense structure provides resistance to moisture, rot and pests, which makes it an ideal material for the production of flooring, stairs, doors, as well as for external structures.

Oak wood is of particular importance in winemaking and the production of alcoholic beverages. Due to its chemical properties, in particular its high tannin content, it gives wine, cognac, whiskey and other beverages unique taste and aromatic characteristics. Barrels made of oak are used to age beverages, allowing them to be enriched with complex woody notes and acquire a softer, more harmonious taste.

Historically, oak wood was the main material for building ships, especially military and merchant vessels. Due to its strength and resistance to water, it was used to make hulls, decks and other important elements of ships, which allowed them to serve for a long time even in extreme conditions. Oak was the main species for shipbuilding in Europe until the 19th century, when it gradually began to be replaced by metal structures.

The productivity of oak stands depends on forest management, stand age and density. The productivity of oak on a site depends on climatic factors, soil type, geology and altitude [13, 44].

Oaks are long-lived trees and can reach an age of over 1000 years in favorable conditions. They grow up to 40 m tall and their trunks can reach a diameter of 4 meters, making them one of the most majestic representatives of European forests. The age of some of the oldest oaks, such as the famous Josef Oak in Poland or the Major Oak in England, is estimated to be several centuries or even more than a millennium, which indicates their unique resilience and adaptive capabilities. Typically, trees of this species reach a height of 25–35 m, with an average trunk diameter of 0.8–1.5 m.

This tree species, like other members of the genus *Quercus*, is characterized by significant morphological variability. Leaf shape, acorn size, bark structure, and other morphological features can vary significantly depending on growing conditions, tree age, and environmental factors.

One of the key features of the common oak is its ability to naturally hybridize with related species such as the holm oak *(Quercus petraea)*, the downy oak *(Quercus pubescens)*, and other *Quercus* species. This results in hybrids that have intermediate morphological characters or show dominance of certain characteristics of one of the parental species.

Because of this, determining whether individual trees belong to the species *Quercus robur* based on morphological observations alone can be a difficult task. In some cases, molecular genetic methods are used for more precise identification, which allow us to detect genetic differences between species and confirm the hybrid origin of individual specimens.

The main trunk of *Quercus robur* tends to gradually disappear into the crown, branching out into massive skeletal branches that often grow in different directions, forming a broad, irregular crown. This is especially noticeable in older trees, which have sprawling, asymmetrical crowns with sinuous branches and numerous small shoots.

The bark of the common oak is smooth and light gray when young, but with age it becomes rougher, acquiring a characteristic deeply fissured structure. Mature trees have thick, rough bark of dark gray or gray-brown color, consisting of elongated, rectangular or irregularly shaped blocks, separated by deep grooves. Due to this structure, the bark performs a protective function, ensuring the tree's resistance to mechanical damage, the effects of pests and diseases, and also preventing excessive moisture loss.

The leaves of common oak (*Quercus robur*) are simple, obovate-oblong, with characteristic deep but irregular lobes, which gives them a unique appearance. The length of the leaf varies within 7–15 cm, width – 4–8 cm. The petiole is short, usually 2–7 mm, which is one of the important diagnostic features that allows you to distinguish *Q. robur* from the similar rock oak (*Quercus petraea*), which has a much longer petiole. The leaves are dark green, shiny above, and lighter below, with a more matte texture. In autumn, it acquires yellow, red or brown shades and usually remains on the tree for a long time, especially in young specimens.

The common oak is a monoecious wind-pollinated species, which means that both male and female flowers are formed on the same tree. The male flowers are collected in long, drooping, yellowish catkins about 5 cm long, which appear on the shoots of the current year. The female flowers are much smaller, inconspicuous, spherical in shape and do not exceed 1 mm in diameter. They are located at the tips of young shoots, most often 1–3 at a time, in the axils of young leaves. Pollination occurs with the help of the wind, which contributes to the wide distribution of pollen and ensures effective fertilization even in sparse stands.

The morphological diversity of oak covers a wide range of characters, including flower structure. Female flowers can be inconspicuous, and the color of the stamens varies. The number of flowers per inflorescence is not a constant and can vary greatly between individuals. This variability affects fruiting productivity, as not all flowers develop into an acorn. However, there is a tendency for the number of acorns to increase on trees with a higher number of flowers per inflorescence [57]. It is interesting that the female flowers of the common oak appear almost simultaneously with the blooming of the first leaves, which in the initial stages of development may have a purple or reddish hue due to the content of anthocyanins – natural pigments that perform a protective function against ultraviolet radiation and temperature changes.

The fruit of the pedunculate oak is acorns, often arranged in pairs and attached to the branches by long stalks (peduncles). This feature gave rise to its common name "pedunculate oak", meaning "stemless" in reference to the leaves, which are attached almost without petioles. Acorns ripen in autumn, usually between September and October, and are an important food source for many species of animals, including squirrels, wild boars, deer and some birds.

The shape and size of acorns can vary considerably depending on the growing conditions of the tree, genetic characteristics and climatic factors. However, typical of *Q. robur* are rounded or slightly elongated acorns, which have characteristic olive-green longitudinal stripes, which are clearly visible when fresh. They are partially covered by a scaly cupula, which consists of numerous woody scales and covers about a quarter to a third of the fruit.

The morphological characteristics of oak fruits (acorns) show considerable variability. Specimens up to 5–6 cm long and 2.5 cm wide have been recorded. However, there are also a significant number of trees that form small, almost spherical fruits, partially immersed in a calyx. The shape of the acorns also varies from thin and elongated to pointed, ovoid and barrel-shaped [25].

The morphological diversity of oak species is manifested, in particular, in significant variations in the leaf blade. The depth of the incisions, the number and shape of the blades, the contours of the leaf base, its color, pubescence, as well as the overall dimensions and length of the petiole are important taxonomic features. A wide range of leaf sizes is observed: from small, no more than 8 cm long and 2–3 cm wide, to large, reaching 20–25 cm long and 12–15 cm wide. Typical leaf sizes are 5–15 cm long and 2–8 cm wide [58].

In the early stages of ontogenesis, oaks demonstrate slow growth rates. Active growth is observed in the age range of 5–20 years, after which the growth intensity of most species decreases. Fruiting occurs relatively late: in natural conditions – at the age of 10–20 years, in culture – 20–30 years [48, 61].

In the past, the natural range of common oak was much wider than it is now. The trend towards a decrease in the area of oak plantations is observed both in Ukraine and in other European countries. The results of the analysis of forest management materials indicate that during the period 2000–2010 the area of oak forests of natural seed origin decreased by 20.5 thousand hectares, or by 6 % [68], that is, by 2 thousand hectares per year.

Throughout its range, *Q. robur* is able to adapt to a variety of climatic and soil conditions. It prefers moist but well-drained soils, although it can also grow in drier places. Due to its resistance to low temperatures, oaks can survive even in the harsh conditions of northern regions, forming large forests. In southern regions, where the climate is more arid, pedunculate oak often grows in mountains or on mountain slopes, which provides it with optimal conditions for growth.

The southern limits of the pedunculate oak's range are difficult to define due to the complex interactions with other oak species that grow in the Mediterranean region. In these areas, *Q. robur* often mixes, competes, and naturally hybridizes with other Mediterranean oaks, such as *Quercus pubescens* (downy oak) and *Quercus frainetto* (franitto oak).

Hybridization between these species can produce individuals with intermediate characteristics, making it difficult to accurately identify the species in the southwestern part of the range. In such areas, oaks often grow in mixed forests, where one oak species may gradually replace another or form complex ecological structures that include several species at the same time.

Furthermore, even in areas with relatively low temperatures, where oaks are not typical forest crops, hybridization processes promote complex ecological interactions between species, which can modify the morphological and ecological characteristics of each species within their natural range. This can also lead to the formation of new ecotypes that are able to survive in specific conditions of the Mediterranean climate, such as greater aridity or high temperatures in summer.

This mixing and competition between species can also affect landscape changes and biodiversity in the region, as different oak species have different ecological niches and requirements for growing conditions [14].

The common oak (*Quercus robur*) can be found at considerable altitudes even in southern regions, where the climate and growing conditions can differ significantly from those of the plains. It is known that this species can grow at altitudes of up to 1300 m above sea level in the Alps, where it forms mixed forests with other mountain tree species. In mountain climates, oaks grow more slowly, but can reach considerable sizes, adapting to changes in temperature and humidity.

High-altitude populations of *Q. robur* often face harsher environmental conditions, such as colder winters, greater temperature extremes, and more frequent winds. However, these trees, like other oaks, are highly resilient to environmental changes. They adapt to the lower rainfall and higher solar radiation that are typical of mountainous regions.

Oaks growing at such altitudes play an important role in maintaining the stability of ecosystems, serving as a basis for many species of flora and fauna that are also adapted to mountain conditions. They provide shelter and food for a variety of animals, including mammals and birds, and perform ecological functions such as protection against soil erosion.

Due to the significant human interest and intensive use of the common oak over many centuries, significant changes have occurred in its distribution, which has led to a disruption of the natural structure and ecological balance. Forests, which were historically widespread over large areas, have often been subject to human intervention: felling of trees, changing landscapes for agriculture and development, and the use of oak wood for construction, furniture and barrel making, as well as for other economic needs.

This has led to a significant reduction in the area of primary oak forests, which has significantly changed their structure. Primary oak forests, which were previously dominant in many regions of Europe, have become fragmented, and more resistant species to anthropogenic influences have appeared in their composition. As a result, natural oak ecosystems have become severely disrupted, and the forest structure in these areas has become very uncertain.

In addition, due to the expansion of agricultural land and other human interventions, oaks have become more common in non-typical ecosystems or as single trees rather than in dense forests. Mixing with other tree species, natural and artificial forest plantations, as well as changes in soil composition have further complicated the process of preserving and restoring the original structure of oak forests.

These changes have serious consequences for biodiversity, the ecological stability of forests and their functions in natural ecosystems. The restoration of natural oak forests requires not only the protection of existing areas, but also careful planning and implementation of silvicultural measures to restore the structure characteristic of primitive ecosystems.

Quercus robur was introduced to the United States in colonial times for its wood, which is renowned for its strength and durability. Originally, common oak was planted in forests and plantations for commercial purposes, including the production of furniture, barrels, and building materials. However, due to its aesthetic qualities and ability to adapt well to new conditions, oak quickly became popular as an ornamental tree in urban parks and gardens.

In some regions of the United States, particularly in the southern and eastern states, *Q. robur* has been able to naturalize, establishing new populations and gaining a foothold in native ecosystems. Over time, these oaks have become part of local forest compositions, although their spread has sometimes been accompanied by competition from native tree species such as *Quercus alba* (white oak) and *Quercus rubra* (red oak).

In addition, due to its popularity and ability to be used decoratively, the common oak has been exported to other continents. For example, it has been introduced to Australia, New Zealand and South Africa, where these oaks are used not only for landscape design, but also for the formation of forest plantations, providing wood and contributing to the improvement of the ecological situation in the regions. Due to its longevity and good endurance, the common oak is able to quickly adapt to different climatic conditions and grow even in arid and temperate zones.

These changes in the geography of the distribution of common oak have become an important part of ecological research and plans for forest restoration on different continents, where it can perform not only economic, but also ecological functions.

One of the main problems of reforestation in the context of sustainable forestry development is the lack of quality reforestation. Reforestation, especially artificial, even despite excessive regulation, does not always ensure quality reforestation, in particular the restoration of biologically stable forest ecosystems that more closely resemble the composition and form of primary forest types [39, 45].

Obtaining planting material of common oak

The impact of reforestation methods, in particular the selection of planting material of common oak (*Quercus robur* L.) and its quality, on the formation of stable and productive forest crops is the subject of long-standing scientific discussions. Despite numerous studies, there is still no universal technique that would provide optimal results in different environmental conditions [38].

The effectiveness of forest restoration is largely determined by the choice and quality of planting material. Current trends demonstrate the growing popularity of using seedlings with a closed root system (CRS). This is especially true for pedunculate oak (*Quercus robur* L.), which is the dominant species of forests in the Left-Bank Forest-Steppe of Ukraine [28, 68].

The process of oak forest regeneration in Ukraine involves the use of both natural and artificial methods. Artificial reproduction of oak is the dominant method, which is due to its biological characteristics, namely the periodicity of seed renewal. According to the literature, oak bears fruit on average once every 5 years. Artificial regeneration of oak is carried out through sowing acorns or planting seedlings with different types of root systems [64].

When choosing the best approach to creating artificial oak plantations, researchers have not yet reached a consensus on the optimal planting material and methodology. Some scientists [35, 66, 94] prefers the traditional method of sowing acorns, arguing that it is natural and economically feasible. Another group of researchers [18, 93] suggests using seedlings with an open or closed root system, considering this method more effective.

The method of creating forest crops by sowing acorns demonstrates high ecological feasibility. It involves minimal human intervention in natural processes and is economically profitable. Plants grown from acorns show greater adaptability to local conditions, in particular, better drought resistance due to a developed root system. The absence of the need for transplantation helps to preserve the integrity of the root system and has a positive effect on the survival of seedlings [46].

One of the promising approaches to restoring forest ecosystems is the use of planting material with a closed root system (CRS) [92]. Unlike traditional seedlings with an open root system (ORS), seedlings with CRS demonstrate significantly higher survival rates due to the preservation of an intact root ball. This allows plants to adapt more quickly to new growing conditions, which leads to a reduction in the period of forest cover restoration. In addition, the use of planting material with CRS contributes to the intensification of growth and development of young trees, increasing the overall efficiency of silvicultural work. [17, 47].

Container growing of tree seedlings has a number of advantages compared to the traditional method of growing with an open root system [81, 86]. Container growing allows you to shorten the time it takes to obtain planting material ready for planting. Seedlings grown in containers have more uniform sizes, which makes their subsequent planting and care easier. Container seedlings can be planted for a longer period, since their root system is protected from damage during transplantation. Container seedlings have better survival in areas with unfavorable soil conditions or insufficient moisture. Container growing creates conditions for better control over germination and seedling development, which is especially important for species with low germination energy and seed germination.

However, container growing also has certain disadvantages [87]. Containers have limited soil volume, which can lead to an imbalance of nutrients needed for plant growth. Container seedling production requires significant costs for the purchase of containers, substrate, and plant care equipment.

The quality of seedlings grown in containers depends on many factors [1, 87], among which the most important are:

- The optimal container size depends on the type of tree, planting density, environmental conditions, and length of the growing season.
- A substrate for growing seedlings that must provide plants with nutrients, moisture, and oxygen, as well as meet the requirements of a specific species.
- Too high a planting density can lead to competition between plants for light, water and nutrients.
- The design of the containers should prevent root curling and provide adequate drainage.

Particular attention should be paid to the problem of root curling in containers, especially for seedlings with a taproot system [87]. To prevent this phenomenon, it is recommended to use containers of special design with ribbed inner walls.

The size of the container plays a crucial role in the development of tree seedlings, as it directly affects the growth of the root system and the above-ground part. A container that is too small leads to limited root growth, their twisting and the formation of a ring system, which negatively affects the plant's resistance to wind and drought in the future. In addition, a small volume of soil dries out quickly, which can lead to overheating of the roots in summer and their freezing in winter. At the same time, a container that is too large can contribute to excessive development of the root system to the detriment of the above-ground part of the plant. Water can also stagnate in a large volume of soil, which leads to rotting of the roots. The optimal size of the container should correspond to the size of the seedling's root system at the time of planting and provide sufficient space for its further growth over a certain period of time. It is also important to take into account the species characteristics of the plant, its age and the duration of cultivation in the container [3].

The material from which the container for tree seedlings is made plays a decisive role in their growth and development. Different materials have different physical and chemical properties that affect the thermal regime of the soil, its moisture capacity, air permeability and other important factors. For example, plastic containers are the most common due to their lightness, durability and relatively low cost. They retain moisture well, but can quickly heat up in the sun, which leads to overheating of the roots. Ceramic containers have better air permeability, but they are heavier and more fragile. Metal containers can heat up strongly in summer and cool down in winter, which also negatively affects the root system. Recently, biodegradable containers made of organic materials have become popular. They are environmentally friendly, but can quickly decompose in the soil. When choosing a container material, it is important to consider the climatic conditions of the region, the type of tree plant and the duration of its stay in the container [32].

The relevance of using polyethylene bags for growing planting material of common oak (*Quercus robur* L.) is due to a set of factors, among which the key ones are economic efficiency, manufacturability and environmental safety. Polyethylene bags, due to their availability and low cost, are economically advantageous for mass production of seedlings. Their use allows to reduce transportation and storage costs, since they have a small weight and volume. In addition, polyethylene, as a material, is relatively strong and durable, which provides protection of the root system of seedlings from mechanical damage during transplantation and transportation [20].

Technologically, the use of polyethylene bags simplifies the process of growing seedlings. They are easily filled with soil mixture, provide good drainage and aeration of the root system, which is critically important for the growth of common oak. Due to the transparency of the material, it is possible to visually monitor the development of the root system, which allows you to take timely measures to prevent diseases and root rot.

An important aspect is the environmental safety of using plastic bags. Modern technologies allow the production of biodegradable polyethylenes that do not harm the environment. The use of such materials minimizes the negative impact on the ecosystem and contributes to the preservation of biodiversity. [54].

However, it is worth noting that the use of plastic bags has certain limitations. They can create a greenhouse effect, which leads to overheating of the root system in high temperatures. To solve this problem, manufacturers offer bags with perforations or special additives that regulate heat transfer.

In general, the use of polyethylene bags for growing planting material of common oak is a relevant and promising direction, which combines economic efficiency, manufacturability and environmental safety. Provided that cultivation technologies are followed and modern materials are used, this method ensures the production of high-quality planting material that meets the requirements of forestry and landscaping.

The substrate for container growing of seedlings must meet the physical, chemical and biological requirements of plants [41]. Peat moss is traditionally used as a substrate, however its use raises environmental concerns due to the destruction of peatlands [40]. Therefore, in recent years, alternative organic materials such as manure compost, rice husk ash and other local components have been actively researched [24, 27, 90, 88]. The use of local components reduces substrate transportation costs and makes seedling production more environmentally friendly.

Watering of tree seedlings in closed root system (CRS) conditions is a critically important factor in their successful growth and development. CRS, represented by a container, limits the roots' natural access to moisture and nutrients, so watering plays a crucial role in providing plants with the necessary resources.

The optimal watering regimen for seedlings with CRS depends on many factors, such as the plant species, container size, soil type, climatic conditions and growth phase. It is important to maintain a balance of soil moisture, avoiding both drying out and overwatering. Drying out can lead to wilting, wilting and even death of the plant, while overwatering can cause root rot and the development of fungal diseases.

To determine if watering is necessary, it is recommended to regularly check the soil moisture to a depth of a few centimeters. If the soil feels dry to the touch, this is a signal to water. It is important to water the plants evenly and sufficiently so that the water reaches the roots. However, excessive watering should be avoided, which can lead to water stagnation in the container.

Particular attention should be paid to watering seedlings with CRS during periods of active growth, flowering and fruiting, when their water needs are highest. It is also important to consider weather conditions: in hot and dry weather, watering may be required more often than in cool and humid weather.

Regular and balanced watering is the key to healthy growth and development of seedlings of woody plants with CRS, providing them with the necessary conditions for successful rooting and adaptation to external environmental conditions [42].

Germination of pedunculate oak (*Quercus robur*) seeds is a complex physiological process influenced by many factors, including temperature, humidity, light and the presence of certain chemicals. Various methods are used to stimulate germination of this type of seed, aimed at overcoming their natural dormancy and providing optimal conditions for embryo development. One of the most effective methods is stratification, which consists in long-term storage of seeds in a humid environment at low temperatures (usually from 0 to 5 °C) for several weeks or months. This mimics natural winter conditions and promotes the activation of enzymes necessary for germination [56].

Another important factor is ensuring sufficient moisture levels. Oak seeds require a significant amount of water to swell and activate metabolic processes. To do this, the seeds are soaked in water for several hours or days before planting, or sown in moist soil that is constantly maintained in a moist state.

Temperature also plays a crucial role in the germination of oak seeds. The optimum temperature for most oak species is between 15 and 25 °C. Temperatures that are too low or too high can slow or stop germination completely.

Light can also affect the germination of oak seeds, although this factor is less significant than temperature and humidity. Some studies show that light can stimulate the germination of some oak species, while other species may germinate better in the dark.

In addition to physical factors, chemical factors can also affect the germination of oak seeds. Some plant hormones, such as gibberellins and cytokinins, can stimulate seed germination. Treating seeds with these hormones can significantly increase the germination rate and accelerate this process [95].

In addition, there are other methods of stimulating oak seed germination, such as scarification (damaging the hard seed coat to facilitate water penetration) and fungicide treatment to prevent the development of fungal diseases that can damage the seeds during germination.

Stratification of acorns is a critical step in preparing oak seeds for germination and successful seedling growth. This process mimics the natural conditions of winter, allowing the seeds to break dormancy and activate the physiological mechanisms necessary for germination. From a scientific point of view, stratification of acorns involves a complex of biochemical and physiological changes that occur under the influence of low temperatures and high humidity [29].

During stratification, enzymes are activated in the acorns that break down germination inhibitors, such as abscisic acid. This helps break dormancy and prepare for active growth. Humidity provides the necessary conditions for hydration of seed tissues and activation of metabolic processes. Low temperatures, usually in the range of 0 to 5 degrees Celsius, inhibit the growth of pathogenic microorganisms and prevent premature germination. The duration of stratification depends on the type of oak and storage conditions, but usually ranges from several weeks to several months [91].

An important aspect of stratification is the correct choice of substrate. It should be moist but not waterlogged, breathable and free of pathogens. Traditionally, sand, sawdust, peat or mixtures of these have been used for stratifying acorns. Modern methods also include the use of special containers with perforations and ventilation to ensure optimal storage conditions.

Effective stratification of acorns is the key to obtaining healthy and viable oak seedlings. This process allows to increase the percentage of seed germination, ensure amicability and simultaneity of shoots, as well as increase the resistance of plants to adverse environmental factors.

Forestry and ecological research is constantly expanding our knowledge of acorn stratification mechanisms and developing new, more efficient methods of seed preparation for sowing. This contributes to the preservation and restoration of oak forests, which are essential for the ecological balance and biodiversity of the planet.

Scarification of acorns is the process of mechanically damaging the hard shell of an acorn to facilitate seed germination. This method is often used to accelerate and increase the germination rate of acorns, especially in cases where natural conditions are insufficient for this. Scarification can involve various methods, such as scoring, grinding, or even cracking the acorn shell. It is important to note that scarification must be carried out carefully so as not to damage the seed core itself. After scarification, the acorns are usually soaked in water or treated with special solutions to stimulate germination. This method is an important tool in forestry and horticulture for the restoration of forest plantations and the cultivation of oak trees [26].

It is important to note that the effectiveness of different methods of stimulating the germination of oak seeds may depend on many factors, such as the type of oak, seed quality, storage conditions, etc. Therefore, to achieve the best results, it is recommended to combine different methods and adapt them to specific conditions.

The timing of acorn sowing is a critically important factor determining the success of oak plantation establishment and development. The optimal time for sowing acorns depends on many factors, including the climatic conditions of the region, the weather conditions of a particular year, the depth of groundwater, and the biological characteristics of the oak.

Traditionally, autumn sowing of acorns is considered the most favorable. Provided that the soil is sufficiently moistened in autumn, the acorns have time to swell and begin to germinate before the onset of frost. This ensures early development of the root system in spring and increases the resistance of seedlings to drought in summer. However, in the event of a severe winter, some of the acorns may freeze, so it is important to take into account climatic risks.

Spring sowing of acorns is also possible, but it has its own characteristics. First, it is important to sow as early as possible so that the acorns have time to germinate before the onset of heat. Second, it is necessary to ensure sufficient soil moisture throughout the entire period of germination and seedling development. Provided these conditions are met, spring sowing can be successful, especially in regions with a mild climate.

Early summer sowing of acorns is a less common practice due to the high risk of drought and soil overheating. The success of such sowing is possible only with artificial irrigation and the creation of optimal conditions for seedling development.

Late summer sowing of acorns is generally ineffective, as the seedlings do not have time to develop sufficiently before the onset of cold weather and may die in winter.

In addition to sowing dates, the success of oak cultivation is influenced by other factors, such as the quality of acorns, the depth of their embedding in the soil, soil preparation before sowing, and care for seedlings after emergence.

Scientific research shows that the right time to sow acorns is one of the key factors in the success of creating long-lasting and sustainable oak plantations [4].

The depth of acorn planting is a critical factor affecting germination and subsequent seedling development. The optimal depth provides the acorn with the necessary conditions for germination, such as sufficient moisture, temperature and aeration. Sowing too shallowly can cause the acorn to dry out quickly and fail to germinate, or the seedling to be vulnerable to damage. Sowing too deep can complicate germination due to insufficient air flow and increased risk of rotting. In addition, the depth of planting affects the development of the seedling's root system. At the optimal depth, the roots have enough space to grow and develop, which provides the plant with stability and access to nutrients. Scientific studies have found that the optimal depth of planting acorns depends on many factors, including soil type, moisture, temperature and acorn size [60].

Pre-sowing soil preparation is a critically important stage for the successful cultivation of pedunculate oak (*Quercus robur*). The survival of seedlings, their growth, and resistance to adverse environmental factors depend on the quality and timeliness of the measures taken.

Scientific studies confirm the effectiveness of pre-sowing soil preparation for common oak. In particular, it has been established that loosening the soil helps to increase the area of absorption of water and nutrients by the root system, which has a positive effect on the growth and development of seedlings. The application of mineral fertilizers, especially nitrogen and phosphorus, provides seedlings with the necessary nutrients in the early stages of development [79].

It is important to note that pre-sowing soil preparation should be carried out taking into account the specific soil conditions and biological characteristics of the common oak. For example, heavy clay soils may require additional loosening and the introduction of organic matter to improve their structure. On acidic soils, liming is necessary to reduce acidity [73].

Care for holm oak seedlings is critically important to ensure their healthy growth and development, as this crop is characterized by slow growth in the initial stages of ontogenesis and is demanding on environmental conditions. Scientifically based care includes a set of agrotechnical measures aimed at optimizing growth factors and minimizing the negative impact of external factors. First of all, it is necessary to ensure optimal soil moisture, especially during the period of acorn germination and shoot formation. Excessive moisture can lead to rotting of seeds and the root system, while insufficient moisture will lead to a slowdown in growth and development. An important aspect is the fight against weeds that compete with oak for nutrients, water and light. Weediness of crops can lead to a significant decrease in their productivity. Various methods are used to combat weeds, including mechanical weeding, mulching and the use of herbicides. Soil loosening is also important, which helps improve aeration and water permeability, which has a positive effect on the development of the oak root system. Loosening is carried out regularly, especially after rains and irrigation. In addition, to provide plants with the necessary nutrients, it is recommended to apply mineral fertilizers. Fertilizers contribute to the active growth and development of oak, increase its resistance to diseases and pests. It is also important to protect crops from diseases and pests that can cause significant damage to young plants. Various methods are used for this, including treatment with fungicides and insecticides, as well as the use of biological protection methods. Finally, it is important to take into account the peculiarities of growth and development of common oak at different stages of ontogenesis and adapt care to the needs of plants. A comprehensive and scientifically sound approach to caring for common oak crops is the key to successfully growing healthy and productive plantations [19].

Effective weed control is a critical factor for the successful cultivation of common oak, especially in the early stages of development. Herbicides, as chemicals that destroy weeds, play a significant role in modern plant protection systems. However, their use requires a scientifically sound approach and consideration of many factors to minimize negative impacts on the environment and culture.

In oak plantations, the use of herbicides has its own characteristics, due to the biological characteristics of the crop and the spectrum of weeds. It is important to consider that oak is relatively resistant to some herbicides, but sensitive to others. Therefore, the choice of the drug, its dosage and treatment timing must be carefully justified [49].

To combat annual cereal and dicotyledonous weeds in holm oak crops, herbicides based on the following active ingredients can be used:

- Glyphosate: a broad-spectrum herbicide effective against a wide range of weeds. Apply before emergence or after harvest of the predecessor crop.
- Oxyfluorfen: a selective herbicide effective against many dicotyledonous weeds. Apply before emergence or after the appearance of 2–4 leaves in oak.
- Pendimethalin: a soil-based herbicide effective against the germination of many weed seeds. Apply before or at the same time as sowing.
- Mesotrione: a selective herbicide effective against some grasses and dicotyledonous weeds. Apply after emergence.
- Nicosulfuron: a selective herbicide effective against grasses and dicotyledonous weeds. Apply after emergence.

To achieve maximum effectiveness and minimize the negative impact of herbicides on the environment, it is important to use an integrated approach to the protection of holm oak crops. This approach involves a combination of different weed control methods, such as:

- Agrotechnical measures: timely soil cultivation, crop rotation, use of high-quality seed material.
- Biological methods: use of beneficial phytophagous insects, antagonist microorganisms.
- Chemical methods: use of herbicides, taking into account their spectrum of action, dosage and processing time.

It is important to note that scientific research in the field of herbology is constantly developing, new drugs and technologies for their application appear. Therefore, to obtain up-to-date and scientifically based information on weed control in oak plantations, it is recommended to contact specialized scientific institutions and specialists [12].

The use of growth stimulants when creating planting material of common oak

Modern agriculture actively uses plant growth regulators as a tool to increase crop resistance to adverse environmental conditions and stimulate the development of generative organs and the root system. According to studies, they contribute to the acceleration of key physiological processes, such as the hydrolysis of carbohydrates and proteins, and the enhancement of photosynthesis. The use of PPP-based preparations in agricultural production includes the treatment of seeds and vegetative parts of plants. In forestry, the use of PPP is an urgent problem due to the decrease in the quality of planting material, which is often associated with soil depletion as a result of prolonged use of herbicides [7, 74].

Substances that affect the rate of plant growth and development are known as growth regulators or phytohormones. Their ability to stimulate or inhibit various physiological processes in the plant body has opened up new opportunities for improving agricultural efficiency [51].

Plant growth promoters are a diverse group of substances that, in small quantities, are capable of activating physiological processes that promote plant growth and development. Their composition may vary depending on their origin and purpose, but they usually contain one or more active components, such as phytohormones, vitamins, amino acids, trace elements, humic substances and other compounds [78].

Phytohormones are key regulators of plant growth. The most well-known of these are auxins, gibberellins, cytokinins, abscisic acid, and ethylene. Auxins are responsible for stem and root growth, gibberellins stimulate seed germination and flowering, cytokinins promote cell division, abscisic acid induces dormancy, and ethylene regulates fruit ripening and leaf fall. Synthetic analogues of these hormones are also used as growth promoters.

Vitamins play an important role in the metabolic processes of plants, promoting their growth and development. The most well-known vitamins used in growth promoters include B vitamins, vitamin C, and vitamin E.

Amino acids are the building blocks of proteins, which are essential for plant growth and development. Some amino acids, such as glycine, alanine, and proline, can also act as signaling molecules that regulate physiological processes.

Microelements such as iron, zinc, copper, manganese, and others are essential for normal plant growth and development. They participate in many enzymatic reactions and other important processes.

Humic substances are complex organic compounds that are formed in the soil as a result of the decomposition of plant residues. They improve the structure of the soil, promote the absorption of nutrients by plants and stimulate their growth. In addition to the listed components, growth stimulants may also contain other substances, such as polysaccharides, organic acids, enzymes and other compounds that promote plant growth and development.

The mechanism of action of growth stimulants is that they affect the physiological processes of plants, activating their growth and development. They can affect cell division, protein synthesis, enzyme activity, hormonal balance and other processes. It is important to note that the effect of growth stimulants depends on many factors, such as the type of plant, its age, growing conditions and the concentration of the drug.

The effectiveness of growth stimulants may vary depending on the specific situation. In some cases, they can significantly increase yield and product quality, while in other cases their use may be ineffective or even harmful. Therefore, before using growth stimulants, it is necessary to carefully read the instructions and follow the manufacturer's recommendations.

The first studies on the use of growth regulators in agriculture were conducted in the USA in the 1930s. The proven high efficiency of these substances contributed to their widespread introduction into crop production starting in the 1950s. This, in turn, stimulated the development of the chemical industry aimed at the production of preparations of this group [5, 9].

In Ukraine, the widespread use of growth regulators in agriculture began at the end of the 20th century [28].

In forestry, growth stimulants can be used to increase the growth rate of trees, improve their survival and resistance to adverse environmental factors. The use of growth stimulants is a promising direction for the intensification of forestry, as it allows you to shorten the period of growing timber and increase the productivity of forest plantations. Growth stimulants can be used at different stages of the life cycle of trees - from seed germination to the formation of adult individuals. For example, treating seeds with growth stimulants promotes their faster germination and development of the root system, which is especially important for species with a long germination period. The use of growth stimulants in the early stages of seedling development promotes their active growth and increases resistance to diseases and pests. In more mature trees, growth stimulants can be used to stimulate the growth of the trunk and crown, which leads to an increase in the volume of wood. It is important to note that the use of growth stimulants should be justified and carried out taking into account the characteristics of a particular type of tree and the conditions of their growth. Uncontrolled use of growth stimulants can lead to negative consequences, such as disruption of the natural balance in the ecosystem and reduction of wood quality [6].

The modern market of plant protection products offers a wide range of phytohormonal preparations, both natural and synthetic in origin. These substances are actively used in agriculture for seed treatment before sowing, spraying seedlings and other agrotechnical measures. Recently, increasing attention has been paid to the use of phytohormones in forestry. Studies by domestic scientists indicate the effectiveness of such preparations as Charkor, Agrostimulin, Sodium Humate, Emistym-S, Tryman-1, Vermistim and Ivin in stimulating the growth and development of various plant species [72, 74].

Biologically active compounds demonstrate a positive effect on various stages of plant development, starting from seed germination. Studies indicate an increase in the germination energy and germination of seeds, stimulation of the growth of the root system and an increase in its ability to absorb water and nutrients (by 25–30 %). This, in turn, contributes to an increase in the resistance of plants to adverse environmental conditions. In particular, in experiments with Scots pine, seed treatment with growth stimulants led to an increase in germination and germination energy by 30–50 %. Spraying young plants with other stimulants contributed to the intensive growth of aboveground and underground parts, which was manifested in an increase in height, stem diameter, needle mass and roots. Similar results were obtained for other tree species, such as Scots birch and common oak [67, 72].

Macro- and microelements included in plant growth stimulants play a crucial role in ensuring their optimal development and productivity. Nitrogen (N) is a key component of proteins, nucleic acids and chlorophyll, contributing to the active growth of vegetative mass. Phosphorus (P) is necessary for the formation of the root system, flowering and fruit formation, and also provides energy metabolism in cells. Potassium (K) regulates water balance, increases resistance to stress factors and improves fruit quality. Magnesium (Mg) is a component of chlorophyll and is involved in the activation of many enzymes. Sulfur (S) is necessary for the synthesis of amino acids and vitamins. Iron (Fe) is a component of hemoglobin and cytochromes, ensuring oxygen transport and participation in redox reactions. Manganese (Mn) activates enzymes involved in photosynthesis and respiration. Boron (B) promotes the growth of pollen tubes and fruit setting. Zinc (Zn) is necessary for the synthesis of growth hormones and proteins. Copper (Cu) is involved in the formation of enzymes that protect plants from diseases. Molybdenum (Mo) is necessary for nitrogen fixation from the atmosphere and metabolism. Each of these elements performs its own unique function, and their balanced combination in growth stimulants provides a comprehensive effect on plants, stimulating their growth, development and increasing yield. In addition, trace elements help increase plant immunity to diseases and pests, improve their adaptation to adverse environmental conditions and improve product quality.

Optimization of seedling growing processes in forest nurseries often involves the use of complex biological products [10]. These preparations, in addition to plant hormones, contain specially selected strains of soil microorganisms. In particular, these may be bacteria capable of mobilizing phosphorus, fixing nitrogen, as well as microorganisms that produce humic substances [8]. The interaction of these microorganisms with the soil stimulates biochemical processes, such as increased synthesis of enzymes and vitamins, activation of decomposition of organic matter and enrichment of the soil with macro- and microelements. As a result, the physicochemical properties of the soil improve, which contributes to increasing its fertility and, as a result, improving the growth and development of seedlings [37, 62, 70, 76].

The use of mycorrhiza to optimize plant nutrition is also relevant. Mycorrhiza, a symbiotic association between fungi and plant roots, plays a crucial role in the functioning of forest ecosystems and the nutrition of tree species. Its importance is difficult to overestimate, especially in the context of modern environmental challenges such as climate change and anthropogenic load. Mycorrhiza provides plants with access to nutrients, in particular phosphorus, nitrogen and trace elements, which are often limited in the soil. Fungal mycelium, which forms an extensive network in the soil, significantly increases the area of absorption by the root system, which increases the efficiency of resource use. In addition, mycorrhiza helps protect plants from pathogens and stress factors such as drought and heavy metals. The use of mycorrhizal preparations in forestry is a relevant and promising direction aimed at increasing forest productivity, their resistance to negative impacts and preserving biodiversity. Mycorrhizal treatment of seedlings before planting promotes their better survival and growth on poor soils, which is especially important for the restoration of degraded forest areas. Research on mycorrhizal systems is also important for understanding ecological processes in the forest and developing effective forest resource management strategies [15].

Material and Methods

Conditions for conducting research

Sumy district is characterized by a moderately continental climate with clearly defined seasons. Winter here is usually cold and snowy, with average January temperatures of about -6.3°C. However, significant cold snaps can occur when the temperature drops below -20°C. Snow cover lasts most of the winter, its height can reach 20–30 cm. Spring in Sumy district comes gradually, the air temperature begins to rise in March, and in April-May warm weather sets in with average temperatures of about +10...+15°C. During this period, short-term frosts and precipitation in the form of rain and sleet are possible. Summer in the district is warm and sunny, with average July temperatures of about +20...+22°C. Maximum temperatures can reach +30°C and above. Precipitation in summer is mainly in the form of showers, sometimes thunderstorms are possible. Autumn in the Sumy district begins with a gradual decrease in temperature in September, and in October-November cool weather sets in with average temperatures of about +5...+10°C. During this period, it often rains, frosts and the first snow are possible.

Sumy district is located in the north-eastern part of Ukraine and is characterized by a moderately continental climate with sufficient moisture. During the year, there is a clear change of seasons, each of which has its own characteristics in terms of the amount and nature of precipitation. Sumy district is characterized by a moderately continental climate with sufficient moisture. During the year, the amount of precipitation is unevenly distributed. Winter is characterized by a small amount of precipitation, mainly in the form of snow. The average amount of precipitation per season is about 100-150 mm. The snow cover lasts for most of the winter, but can be unstable due to frequent thaws. Spring is characterized by a gradual increase in the amount of precipitation. During this period, rain falls, sometimes with snow. The average amount of precipitation per season is about 150-200 mm. Summer is the wettest period of the year. At this time, the largest amount of precipitation falls in the form of showers, sometimes with hail. The average amount of precipitation per season is about 250–300 mm. Autumn is characterized by a gradual decrease in precipitation. During this period, rains prevail, sometimes with wet snow. The average amount of precipitation per season is about 150–200 mm. In general, about 600–700 mm of precipitation falls in the Sumy district during the year. The greatest amount of precipitation is observed in summer, the least - in winter. Air humidity throughout the year fluctuates within 70–80 %.

Romensky district, like most of Sumy region, is characterized by a moderately continental climate. This means that it is characterized by relatively warm summers and cold winters. Summers are usually long and warm. Average July temperatures range from +20...+22 °C. However, hot days with air temperatures above +30 °C are often observed. Precipitation in the summer period falls mainly in the form of showers, often accompanied by thunderstorms. Winter is relatively cold. The average temperature in January is usually around -6... -8 °C. A characteristic feature of winter is unstable weather with frequent thaws and snowfalls. Snow cover is established, as a rule, in the second half of December and persists until March. Spring and autumn are transitional, with changeable weather. Spring is characterized by gradual warming, often with frosts at night. Autumn is a period of gradual temperature decrease, with frequent fogs and rains.

This region is characterized by warm summers with moderate precipitation, distributed mainly in the form of showers. Winters are moderately cold with relatively stable snow cover. The growing season is quite long. The uneven distribution of precipitation throughout the year can lead to periodic droughts, especially in the summer. At the same time, sufficient precipitation throughout the year, especially in the spring-summer period, provides optimal conditions for the development of vegetation. Rivers and other water bodies flowing through the region also play an important role in moistening.

Sumy region is characterized by a significant diversity of soil types, which is due to its geographical location and geological history. In the north of the region, in the Polissya zone, sod-podzolic soils predominate, which are characterized by a light mechanical structure and low humus content. In the central part of the region, in the Forest-Steppe zone, meadow-chernozem soils are widespread, which are more fertile and have a higher humus content. In the south of the region, in the Steppe zone, typical and ordinary chernozems are found, which are the most fertile soils of the region. In addition, other types of soils are also found in the territory of Sumy region, such as gray forest soils, meadow soils, swamp soils and others. The soil diversity of Sumy region determines the richness of its plant world and creates favorable conditions for the development of agriculture.

In Sumy district, various types of soils prevail, which is due to the geomorphological features of the territory and its location within the forest-steppe zone. The most common are black soils, which are characterized by high fertility and humus content. They occupy a significant area of the district, especially in its central and southern parts. According to various estimates, black soils make up from 50 to 70 % of the soil cover of Sumy region.

In addition to black soils, the district also has gray forest soils, which are mainly distributed in the northern and western parts. They are characterized by a lower humus content and require additional application of organic fertilizers to increase fertility. Gray forest soils occupy about 20–30 % of the district's territory.

In the floodplains of rivers such as Psel, Sula and others, meadow soils are widespread, characterized by high humidity and organic matter content. They are used for growing vegetables and haymaking. Meadow soils make up about 5–10 % of the soil cover of the region.

In the southeastern part of the district, there are also solonetzic soils, which are characterized by a high salt content and require reclamation for use in agriculture. They occupy a small area, about 2–5 % of the territory.

In general, the soil cover of the Sumy district is quite diverse and is characterized by a significant spread of fertile black soil, which creates favorable conditions for the development of agriculture. However, it is important to take into account the characteristics of each type of soil and apply appropriate agrotechnical measures to preserve and increase their fertility.

In the Romensky district of the Sumy region, various types of soils prevail, among which the most common are chernozems, characterized by high fertility and humus content. According to various estimates, chernozems occupy about 60–70 % of the district's territory. Among them, typical chernozems, podzolized chernozems and meadow-chernozem chernozems are distinguished. In addition to chernozems, gray forest soils are also found in the district, which are formed under forest vegetation and have a lower humus content, their share is about 20–25 %. In the lower areas of the relief, where there are conditions for moisture accumulation, meadow and meadow-marsh soils are common, occupying about 5–10 % of the territory. It is important to note that a significant part of the district's soils have been subjected to anthropogenic impact, in particular, plowing and the use of fertilizers, which could have led to a change in their properties.

Object, subject and research methodology

The aim of the work is to study the technology of growing planting material of common oak (*Quercus robur* L.) and determine the features of their growth and development (adaptation) depending on the methods of obtaining and using foliar feeding with growth stimulants in the conditions of the Left-Bank Forest-Steppe of Ukraine.

The object of research is planting material of common oak, the technology of obtaining planting material and the use of growth stimulants in the conditions of the Left-Bank Forest-Steppe of Ukraine.

The subject of research is growth and development of common oak planting material.

To achieve this goal, we planned the following **tasks**:

- determine the survival rate of holm oak seedlings depending on the methods of obtaining planting material (open and closed root system) and the use of growth stimulants;
- establish biometric indicators (height of woody plants, height gain, root collar diameter) of holm oak planting material depending on the method of obtaining and using growth stimulants.

Research methods. In order to achieve the set objectives, the following methods were used: field observations of the growth and development of planting material, morphometric measurements and statistical data analysis. Morphometric parameters (height, root collar diameter) were measured using appropriate instruments. Statistical data processing was carried out using Statistica 8.0 software.

Results

Forestry in Ukraine is aimed at optimizing the use of forest resources to meet public needs. At the same time, the key task of the industry is to ensure balanced forest regeneration and rational use of their ecosystem services in order to achieve sustainable development of the forest sector. In order to optimize forestry practices, it is necessary to conduct a detailed analysis of existing forest crops using a typological approach. Systematization of many years of experience in silvicultural production will allow determining the most productive and sustainable forest stands for each specific type of forest. The results obtained will serve as the basis for developing effective silvicultural measures [77].

In the context of global climate change and anthropogenic pressure on forest ecosystems, the issue of restoring and preserving oak stands is becoming particularly relevant for Ukraine. Common oak (*Quercus robur* L.) is one of the most valuable forest-forming species, which plays an important role in shaping the ecological balance and ensuring the economic stability of the country. However, the current state of oak forests is characterized by a tendency to reduce the area and deteriorate their condition. One of the key problems is the insufficient and poor-quality reproduction of oak stands, which is due to the complexity of growing planting material of this species. Traditional methods of growing oak are often ineffective and do not provide a sufficient number of high-quality seedlings. In this regard, there is an urgent need to conduct comprehensive scientific research aimed at improving the technology of growing oak planting material in Ukraine.

Such studies should cover a wide range of issues, including:

- Study of the biological characteristics of oak: study of the processes of growth and development of oak at different stages of ontogenesis, identification of factors affecting its productivity and resistance to adverse conditions.
- Development of effective propagation methods: optimization of technologies for obtaining high-quality seed material, development of methods for vegetative propagation of oak, in particular, microclonal propagation in vitro.
- Improvement of cultivation technologies: development of modern methods for growing oak seedlings in closed and open soil conditions, optimization of irrigation, nutrition and plant protection modes from pests and diseases.

• Breeding and genetics: identification and selection of the most promising oak genotypes, creation of varieties with high productivity, resistance to diseases and adaptability to various environmental conditions.

• Economic efficiency: assessment of the economic feasibility of implementing new technologies for growing oak planting material, development of recommendations for forestry enterprises.

Conducting such research is vital for ensuring the sustainable development of Ukraine's forestry, preserving biodiversity and the country's environmental security. The results of the research should be implemented in silviculture practice, which will allow increasing the area of oak plantations, increasing their productivity and sustainability, as well as ensuring the needs of the forest industry in high-quality wood.

Experiment 1. Modern methods of obtaining planting material of common oak in the conditions of the Sumy Forestry Branch of the State Enterprise Forests of Ukraine

It is currently known that acorns can be sown in spring or autumn. During autumn planting and harvesting, the oak fruits undergo a real stratification. During spring planting, you need to wait until the soil has finally warmed up.

Our work is devoted to studying the optimal planting dates.

So, the first stage is planting in autumn (Fig. 1).

Fig. 1. *Autumn sowing of Quercus robur L. acorns in the conditions of the Sumy Forestry Branch of the State Enterprise Forests of Ukraine (photo by Legusha Roman)*

The second is stratification in a pit and subsequent spring sowing. To prevent rotting or, conversely, drying out of acorns (during the thaw), the fruits are planted to a depth of 7–10 cm in the soil during autumn planting. During spring planting, it is enough to bury the acorns by 4–5 cm. To avoid eating acorns by animals and mold, in the presence of heavy rainfall, young autumn plantings must be covered with waterproof material.

It is advisable to sow oak fruits in moistened grooves, observing an interval of 10–30 cm. When planting sprouted acorns, this should be done carefully, since the young roots are very fragile and fragile. Sprouted acorns can be planted immediately in open ground or in a container (most often a plastic cup is used) for further germination. Generally, care for sprouted acorns is aimed at watering and providing a sufficient amount of light. Seedlings that have grown (if there are 2–3 leaves) are dived into large containers or transplanted immediately to the garden bed.

Table 1 illustrates the results of a study of the influence of planting dates on soil germination and survival of pedunculate oak (*Quercus robur* L.) seedlings in the conditions of the Sumy Forestry Branch of the State Enterprise Forests of Ukraine. Analysis of the obtained data indicates a clearly expressed dependence between the planting date and the success of seedling establishment and growth.

Soil germination, which reflects the percentage of germinated acorns, is a critically important indicator for the success of silvicultural activities. The results of the study show that spring sowing provides significantly higher soil germination (85.2 %) compared to autumn sowing (71.5 %). This difference is 13.7 %, which is statistically significant ($p < 0.05$). Higher germination in spring is due to favorable conditions for acorn germination, such as sufficient soil moisture and optimal temperature. The spring period is also characterized by a lower number of soil pathogens and pests, which also contributes to better germination.

The seedling survival indicator, which reflects the percentage of plants that have survived for a certain period after planting, also shows better results for spring planting. The survival of holm oak seedlings in spring sowing is 78.7 %, while in autumn it is only 65.8 %. The difference of 12.9 % is also statistically significant ($p < 0.05$). The higher survival of seedlings in spring is explained by the fact that plants have time to develop a sufficient root system before the onset of winter cold, which provides them with better resistance to adverse weather conditions. In addition, spring seedlings have more time to adapt to environmental conditions and form mechanisms for protecting against diseases and pests.

The results obtained are consistent with the well-known patterns of growth and development of woody plants. The spring period is optimal for planting most tree species, since it is at this time of year that the most favorable conditions for their establishment and growth are created.

Table 1. Soil germination and survival of pedunculate *Quercus robur* L. seedlings depending on the planting date in the conditions of the Sumy Forestry Branch of the State Enterprise Forests of Ukraine.

Sowing date	Soil similarity, %	Survival, %
Spring	85,2	78,7
Autumn	71,5	65,8
Duncan test $_{0,05}$	9,5	5,9

Acorns germinate slowly: the root grows first, then the shoot. The first shoots appear only 1–1.5 months after planting (Fig. 2).

We use the planting rate of acorns – 125 g/l. m. The depth of the wrapping is 5–7 cm. If you use an area where oak has not previously grown, it is necessary to apply mycorrhizal soil (especially for oaks) in the amount of 100 l/p. m. or a culture of mycorrhizal fungus.

In order to obtain a fibrous root system, the roots should be pruned after the appearance of the first pair of true leaves with a root pruner KN-1.2. In the event of focal powdery mildew, the seedlings should be treated with a 0.5 % sulfur solution or other similar preparations, the treatment is repeated after 2–3 weeks continuously. The weed protection system is the main component of the technology for obtaining planting material.

a **b**

Fig. 2. *Germination of Quercus robur L. acorns in the conditions of the Sumy Forestry Branch of the State Enterprise Forests of Ukraine:*
a – seedlings on 05/26/2023; b – seedlings on 11/9/2023

To prevent weeds from growing, the following herbicides can be used immediately 3–5 days after sowing: simazine 1–2 kg/ha, propazine – 2–4 kg/ha. Dissolve in 500 l of water. For loosening the soil in the rows, cultivators KRSSH-2.8A, KFP-1.5 are used. The number of cultivations in the first year is 4–6, in the second year 2–4. Before sowing, the fruits (acorns) should be treated with pesticides, for example, fentiuram. We noted the advantages of spring sowing. In particular, acorns germinate best in spring, as this is associated with better soil moisture. The main condition for good storage of acorns is to maintain a high moisture content in them. Soil germination during spring sowing was 85.2 %, which is 13.7 % higher compared to the autumn period.

The table 3.2 contains data on the morphometric parameters of pedunculate oak seedlings obtained in the conditions of the Sumy Forestry Branch of the State Enterprise Forests of Ukraine in 2023, depending on the date of planting acorns.

The total length of the seedling is an important indicator characterizing the overall development of the plant. As can be seen from the table (Table 2), this parameter is larger in seedlings planted in spring (53.80 cm) compared to those planted in autumn (48.70 cm). The difference is 5.1 cm, which may indicate better conditions for the growth and development of seedlings during the spring planting period.

Stem length is also an important morphometric indicator, as it characterizes the above-ground part of the plant, where photosynthesis and other important physiological processes occur. In spring seedlings, the stem length (25.80 cm) also exceeds the similar indicator in autumn ones (19.20 cm). This difference is quite significant – 6.6 cm, which may indicate a more active growth of the above-ground part in the spring period.

Root length is a critically important parameter, as the root system provides the plant with water and nutrients from the soil. It is interesting to note that, despite the smaller size of the above-ground part of autumn seedlings, their root length (30.50 cm) is slightly higher than that of spring seedlings (28.1 cm). This is probably due to the fact that autumn seedlings direct their resources more to the development of the root system to better survive the winter period.

The Duncan test criterion ($p < 0.05$) is used to statistically assess the difference between the variants. In this case, the Duncan test values for all three morphometric parameters are less than the critical value of 4.50 for the total seedling length, 3.80 for the stem length and 2.50 for the root length.

This indicates that the difference between spring and autumn seedlings for these parameters is statistically significant.

Table 2. Morphometric parameters of pedunculate *Quercus robur* L. seedlings depending on the time of planting acorns in the conditions of the Sumy Forestry Branch of the State Enterprise Forests of Ukraine (2023)

Acorn planting time	Total seedling length, cm	Barrel length, cm	Root length, cm
Spring	53,8	25,8	28,1
Autumn	48,7	19,2	30,5
Duncan test $_{0,05}$	4,5	3,8	2,5

The term of planting acorns has a significant impact on the morphometric parameters of pedunculate oak seedlings. Spring seedlings are characterized by a greater total length and trunk length, which indicates their more active growth and development. At the same time, autumn seedlings tend to have a better development of the root system, which may be an adaptation to adverse winter conditions. It should be noted that the total linear dimensions (trunk and root) were higher in spring-sown pedunculate oak acorns (Fig. 3.).

The mass of the seedling is an integral indicator that reflects the overall development of the plant and its ability to photosynthesise and accumulate organic matter. According to the presented data, seedlings planted in spring have a greater mass (6.50 g) compared to autumn ones (5.10 g). This difference may be due to the fact that spring seedlings have more time to grow and develop during the growing season, since autumn seedlings must survive the winter period, which can lead to the loss of some resources and a slowdown in growth.

а б

Fig. 3. *Photos of seedlings at different planting dates of Quercus robur L. acorns in the conditions of the Sumy Forestry Branch of the State Enterprise Forests of Ukraine: 1 – spring; 2 – autumn (photo by Melnyk Andrii)*

The diameter of the root collar is an important morphometric indicator that characterizes the development of the root system and its ability to absorb water and nutrients from the soil. As can be seen from the table, the diameter of the root collar in spring seedlings (0.320 cm) is also larger than in autumn seedlings (0.250 cm). This may indicate that spring seedlings have a better developed root system, which provides them with better adaptation to environmental conditions and resistance to stress factors.

Chlorophyll content is an important physiological indicator that reflects the intensity of photosynthesis and the ability of the plant to form organic matter. The results of the study show that the chlorophyll content in spring seedlings (44.90 SPAD units) is significantly higher than in autumn seedlings (32.10 SPAD units). This may be due to the fact that spring seedlings have more favorable conditions for photosynthesis, as they receive sufficient sunlight and heat during the growing season.

In this case, the Duncan test values for all three parameters are less than the critical value. This indicates that the difference between spring and autumn seedlings in these parameters is statistically significant.

a b

Fig. 4. *Determination of the diameter of the root collar (a) and the weight of seedlings (b) at different planting dates of Quercus robur L. acorns in the conditions of the Sumy Forestry Branch of the State Enterprise Forests of Ukraine (photo by Sonora Yevhenii)*

Chlorophyll content is an important indicator characterizing photosynthetic activity, and accordingly the accumulation of organic matter. Using the SPAD N-tester (Minolta, Japan), absolute values were determined in the leaves of oak seedlings depending on the date of plantation establishment.

Table 3. Root mass and diameter of the (root) neck of pedunculate *Quercus robur* L. seedlings depending on the time of planting acorns in the conditions of the Sumy Forestry Branch of the State Enterprise Forests of Ukraine (2023)

Acorn planting time	Seedling weight, g	Root collar diameter, cm	Chlorophyll content in SPAD units
Spring	6,5	0,32	44,9
Autumn	5,1	0,25	32,1
Duncan test $_{0,05}$	0,9	0,08	8,5

Thus, significantly higher indicators were obtained in plants with spring sowing of acorns, namely 44.9 SPAD units compared to 32.1 SPAD units with autumn sowing.

Therefore, this term contributes to the formation of holm oak seedlings with higher morphological, weight and physiological indicators, which determines their better subsequent adaptation in forest crops.

Experiment 2. Modern methods of obtaining planting material of *Quercus robur* L. in the conditions of the Bishkino base nursery of the Lebedyn Forestry Branch of the State Enterprise Forests of Ukraine

First of all, it is important to collect good - planting material from common oak. It is best to collect acorns in the fall during dry weather, when they are fully ripe. The cap, which protects the fruit from damage, is easily separated during this period. Oak fruits should be intact and without any signs of rot or damage, such as cracks or rodent marks. Viable oak fruits should be planted directly into the soil. You can plant as in open ground (details will be given in the next section).

To determine the viability of acorns, inspect their contents. The core of dead fruits will be dark in color, while in living fruits it will be cream in color with a visible embryo.

When storing acorns, after collecting them, leave them to dry for 1-2 weeks at room temperature. After drying, acorns should be stored in a cool place at a temperature of 0- + 2 °C and a high level of humidity. This can be a cold store or a deep basement. After a year of storage, acorns significantly lose their viability.

It should also be noted that there is a high probability of death if stored in airtight bags or closed containers. During storage, it is recommended to periodically remove the acorns and check them for mold. If mold is present, they should be washed and returned to the refrigerator.

A water test is possible to evaluate oak planting material: dry fruits float when soaked, while viable ones sink to the bottom. Also, if they are dark in color, they should not be used for planting.

There is a simpler (natural) way to store acorns in the winter - they can be buried in the ground on the site to a depth of 20–25 cm. The storage location should be marked and covered with waterproof material.

Acorns can be planted directly in a permanent place or seedlings can be grown beforehand and then transplanted into forest crops. Planting can be done in both spring and autumn. During autumn planting (immediately after harvest), acorns undergo natural stratification and prepare for spring planting, showing a healthy and hardened sprout. In autumn, they are planted in a garden bed about 1 month before the first frost.

It is currently known that acorns can be sown in spring or autumn. In autumn sowing, which occurs after the oak fruit is harvested, natural stratification occurs. For spring planting, you should wait until the soil has fully warmed up.

At the beginning of sowing acorns, it is recommended to soak them in gas to protect them from animals and rodents. Some farms use the German drug HUKINOL before sowing - a means to scare away wild animals, which has a rather specific smell. In this way, we are sure that for the next 3-4 months, deer and wild boars will not enter the plot and will not destroy the young shoots that are sprouting.

Caring for sprouted acorns includes regular watering and providing sufficient light (Figure 5).

Seedlings of common oak were grown in polystyrene foam boxes (cassettes) 15 cm deep, which had 40 holes with an upper diameter of 5.5 by 5.5 cm, as well as in plastic bags 30 cm high and 12 cm in diameter.

The resulting mixture was filled and well tamped into polyethylene bags, in which 4 drainage holes with a diameter of 5 mm were previously punched using a stationery hole punch. The bags with the soil mixture were transported across the nursery to a specially prepared site with a drainage gravel-crushed cushion, placed tightly to each other and watered abundantly to compact the soil.

Fig. 5. *Appearance of Quercus robur L. seedlings with an open root system in the conditions of the Bishkino base nursery of the Lebedyn Forestry Branch of the State Enterprise Forests of Ukraine (photo by Dudka Anhelina)*

The acorns sorted after stratification were sown, depending on weather conditions, in the soil mixture prepared in this way after the establishment of a stable spring period without significant spring frosts in March-April. For this purpose, 2–3 centimeter depressions were made in the soil mixture with wooden shovels, into which the selected acorns were placed sideways, and they were covered and compacted with soil mixture on top, which significantly shortened the germination period. Figure 6. shows a general view of the common oak with a closed root culture.

After sowing acorns, the moist environment in the soil mixture of the containers was maintained at 60–80 % of its full moisture capacity and additional fertilization with ammonium nitrate was carried out. This contributed to the appearance of the first shoots of common oak plants within 1–2 weeks. At the same time, ongoing control was provided, and if pests or signs of seedling diseases were detected, chemical measures were taken to control them using backpack sprayers.

Fig. 6. *Appearance of Quercus robur L. seedlings with a closed root system: in polyethylene bags (B) in the conditions of the Bishkino base nursery of the Lebedyn Forestry Branch of the State Enterprise Forests of Ukraine (photo by Chemerys Oleksandr)*

Insecticides were used to combat aphids and leaf-eating pests. Foliar feeding with complex macro- and micronutrients was also carried out 3–4 times during the plant growing season.

During the growing season, 6–7 treatments of container plants of common oak against powdery mildew were carried out. In order to stimulate the development of lateral roots in the period from late June to early July, containers with oak plants were rearranged to ensure reliable retention of roots in the soil mixture after the release of woody plants from the container during their planting in a permanent place in forest crops in reforestation areas. At the same time, plants were sorted by size, leaving the weaker ones for growing the following year.

The main thing is proper conditions for moistening the soil mixture in containers at 60–80 % of full moisture capacity. This was achieved by systematically watering the plants from the moment the acorns were sown until mid-September – early October, taking into account the specific weather conditions of each year.

To avoid leaf burns, plants were watered daily with automatic sprinklers after sunset or before sunrise, the duration of which depended on the presence of precipitation and temperature. In case of weeds, they were removed manually 2-3 times during the growing season.

The height of the above-ground part is an important morphometric indicator that characterizes the growth and development of the plant. As can be seen from the table (Table 4), the lowest height is for seedlings grown with an open root system (control group)– 31.50 cm.

The use of a closed root system contributes to an increase in the height of seedlings. Thus, seedlings grown in cassettes have a height of 32.30 cm, which is 0.80 cm more than in the control group. The greatest height is achieved by seedlings grown in plastic bags – 35.70 cm, which is 4.20 cm more than in the control group.

The excess over control is an important indicator that demonstrates the effectiveness of using different cultivation methods. As can be seen from the table, the use of a closed root system in cassettes provides an excess over control of 0.80 cm, while the use of plastic bags provides a significantly larger excess of 4.20 cm.

The Duncan test value is 3.20 cm. This means that the difference between the options is statistically significant because it exceeds this criterion.

Table 4. Height of annual seedlings of *Quercus robur* L. under the studied growing methods in the conditions of the Bishkino base nursery of the Lebedynskoe Forestry Branch of the State Enterprise Forests of Ukraine

Method of obtaining planting material	Height of the above-ground part, cm	Before control (open root system), cm
Open root system (K)	31,5	
Closed cassette root system	32,3	0,8
Closed root system plastic bags	35,7	4,2
Duncan test $_{0,05}$		3,2

Therefore, the cultivation method has a significant impact on the height of one-year-old holm oak seedlings. The use of a closed root system, especially in plastic bags, contributes to an increase in the height of seedlings compared to the traditional cultivation method with an open root system.

The next important indicator is the diameter of the trunk near the root of oak seedlings. This is how we determined this indicator using a caliper. The maximum average value (6.1 mm) was for plants with a closed root system in plastic bags (Table 5).

Table 5. Trunk diameter of one-year-old seedlings of *Quercus robur* L. under the studied growing methods in the conditions of the Bishkino base nursery of the Lebedynskoe Forestry Branch of the State Enterprise Forests of Ukraine

Method of obtaining planting material	Trunk diameter at the root collar, mm	Before control (open root system), mm
Open root system (K)	4,7	
Closed cassette root system	5,2	0,5
Closed root system plastic bags	6,1	1,4
Duncan test $_{0,05}$		1,1

The minimum values of this indicator were for seedlings grown in open ground – 4.7 mm. Seedlings in cassettes were formed somewhat thicker than the control – 5.2 mm. The calculated Duncan test was at the level of 1.1 mm.

Biometric parameters are important indicators of plant growth and development, but for a complete analysis of the impact of methods of obtaining planting material, we weighed the seedlings on scales.

To compare the weight of planting material depending on the methods of obtaining, we took 25 plants of each variant. The total weight and the weight of the root system of the seedlings were determined.

Table 6. Total and mass of the root system of annual seedlings of *Quercus robur* L. under the studied cultivation methods in the conditions of the Bishkino base nursery of the Lebedynskoe Forestry Branch of the State Enterprise Forests of Ukraine

Method of obtaining planting material	Seedling, g	Root system, g
Open root system (K)	4,4	2,8
Closed cassette root system	6,2	3,9
Closed root system plastic bags	7,5	4,8
Duncan test $_{0,05}$	2,1	1,5

Thus, among the unweighted indicators of the mass of annual plants Quercus robur L. were: in the control 4.4 g; closed root system in cassettes – 6.2 g; closed root system in polyethylene bags – 7.5 g. Therefore, the plants obtained in polyethylene bags had a significantly greater weight. Duncan test 2.1 g with a difference between the control 3.1 g.

The weight of the seedling root system should be determined separately: with an open system - 2.8 g; with a closed system in cassettes – 3.9 g; in plastic bags – 4.8 g.

Thus, for all parameters of plant growth and development, a positive effect was found when growing seedlings with a closed root system in polyethylene bags. Higher than with an open root system, the results of growth and development of Quercus robur L seedlings were obtained when growing in cassettes. The priority among these methods will be determined by the possibility of greater mechanization of the processes of planting material production and the reduction of manual labor in the creation of forest crops.

Experiment 3. Features of growing planting material *Quercus robur* L. in the conditions of the Nedryhaylivka forestry of the Sumy Forestry Branch of the State Enterprise Forests of Ukraine

The survival rate of planting material is one of the most important indicators of the success of creating forest crops. It determines the percentage of planted plants that successfully take root in a new place and continue to grow. This indicator directly affects the effectiveness of reforestation, the productivity of future forest plantations and their resistance to adverse environmental factors.

According to the results of research conducted in 2024, it was found that the highest percentage of survival by factor A (Table 7) was for planting material with a closed root system (CRS) – 86.7 %. A somewhat lower percentage of survival was for planting material with an open root system (ORS) – 81.5 %.

According to factor B (foliar top dressing), the highest survival rate was observed in the variant with the treatment of planting material after the appearance of true leaves in oak with the growth stimulator Megafol – 88.3 %. The lowest value was obtained in the control variants (without treatment) – 79.9 %.

Table 7. Survival of *Quercus robur* L. in 1-year-old forest cultures created by planting material with open and closed root systems depending on foliar feeding in the conditions of the Nedryhaylivka forestry of the Sumy Forestry Branch of the State Enterprise Forests of Ukraine

Creation method (Factor A)	Nutrition (Factor B)	Survival rate, %	Average by factor B
Seedlings (ORS)	The control	77,3	79,9
	Megafol	85,6	88,3
	Average	81,5	
Saplings (CRS)	The control	82,4	
	Megafol	91,0	
	Average	86,7	

Thus, it can be concluded that the use of growth stimulants has a positive effect on the survival of common oak in 1-year-old forest cultures created by seedlings with both open and closed root systems by an average of 8.4 %.

According to the results of the analysis of variance (Fig. 7), it was found that the greatest influence on the survival rate of pedunculate oak planting material was factor B (growth stimulants) – 72 %. The method of creating planting material (factor A) influenced 24 %.

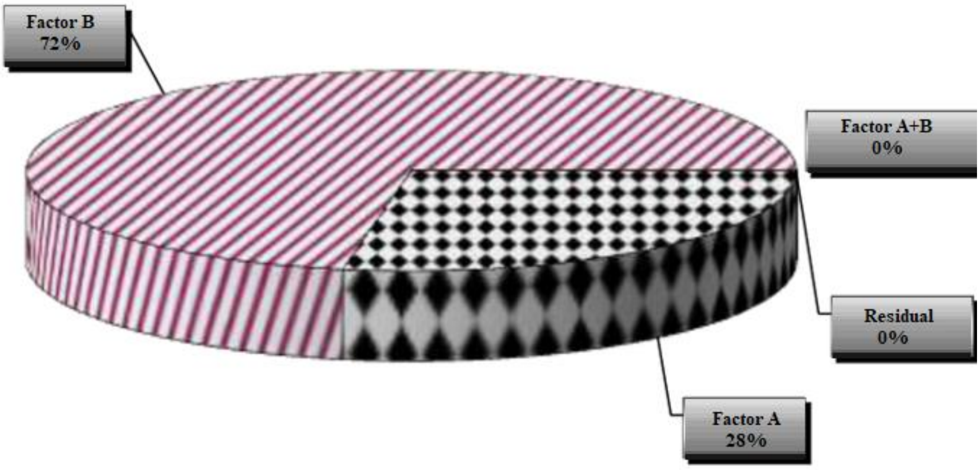

Fig. 7. *The share of influence of factors on the survival of Quercus robur L. in 1-year-old forest cultures created by seedlings with open and closed root systems depending on foliar feeding*

The height of planting material plays a significant role in forestry, horticulture and other industries related to plant cultivation. This parameter not only characterizes the age stage of the plant, but also has a direct impact on its further development, survival and productivity. The height of the seedling affects its competitiveness in natural conditions or in cultivated plantings. Taller seedlings, as a rule, reach reproductive maturity faster and have higher productivity [43].

During the research (Table 8), it was found that according to factor A (Methods of creation), the highest were seedlings with a closed root system – 24.4 cm. The lowest were seedlings with an open root system – 20.1 cm.

In terms of factor B, it was found that foliar feeding with Megafol had a positive effect on the height of planting material – 26.0 cm. The lowest were seedlings on control options – 18.4 cm.

In general, within the framework of the experiment, the tallest plants were obtained from seedlings with a closed root system with foliar feeding with a growth stimulator – 28.4 cm, the lowest - from seedlings with an open root system without treatment with a growth stimulator – 16.5 cm.

Table 8. Height of planting material of *Quercus robur* L. with open and closed root systems depending on foliar feeding in the conditions of Nedryhaylivka forestry of the Sumy forestry branch of the State Enterprise Forests of Ukraine, cm

Creation method (Factor A)	**Nutrition (Factor B)**	**Height, cm**	**Average by factor B**
Saplings (ORS)	The control	16,5	18,4
	Megafol	23,6	26,0
	Average	20,1	
Saplings (CRS)	The control	20,3	
	Megafol	28,4	
	Average	24,4	

The growth rate of woody plants in height is an important physiological process that significantly affects the development of forest stands. The dynamics of tree height reflects the overall viability of plants and their sensitivity to various environmental factors and agrotechnical techniques.

As for the previous indicator, the height increase of common oak (Table 9) in 1-year-old forest cultures was significantly greater than that created by seedlings with a closed root system – 11.6 cm. Plants in forest cultures created by seedlings with an open root system were characterized by a smaller height increase – 9.2 cm.

With foliar feeding with the growth stimulator Megafol, the greatest increase in the height of common oak was obtained in 1-year-old forest crops created by seedlings with both closed and open root systems– 12.7 and 9.2 cm, respectively. For variants without feeding, this figure was 1.3–2.2 cm lower compared to variants with the use of the growth stimulator.

The diameter of the root collar is one of the most important morphometric indicators of planting material, which directly affects its quality, survival rate and further growth and development of plants. This parameter characterizes the thickness of the stem at the point of transition from the root to the above-ground part of the plant and is a reflection of the general condition of the plant, its physiological activity and growth potential.

Table 9. Height growth of *Quercus robur* L. in 1-year-old forest cultures created from planting material with open and closed root systems depending on foliar feeding in the conditions of the Nedryhaylivka forestry of the Sumy Forestry Branch of the State Enterprise Forests of Ukraine

Creation method (Factor A)	**Nutrition (Factor B)**	**Height gain, cm**	**Average by factor B**
Seedlings (ORS)	The control	7,9	9,2
	Megafol	9,2	11,0
	Average	8,6	
Saplings (CRS)	The control	10,5	
	Megafol	12,7	
	Average	11,6	
Duncan test		1,9	

The largest indicators of the root collar diameter within the experiment (Table 10) were obtained from planting material with a closed root system (factor A) - 4.10 mm. Smaller indicators were characterized by planting material with an open root system - 3.72 mm.

Table 10. Diameter of the root collar of the planting material of *Quercus robur* L. with an open and closed root system depending on foliar feeding in the conditions of the Nedryhaylivka forestry of the Sumy Forestry Branch of the State Enterprise Forests of Ukraine

Creation method (Factor A)	**Seed treatment (Factor B)**	**Root collar diameter, mm**	**Average by factor B**
Seedlings (ORS)	The control	3,33	3,5
	Megafol	4,11	4,3
	Average	3,72	
Saplings (CRS)	The control	3,61	
	Megafol	4,58	
	Average	4,10	
Duncan test		0,7	

According to factor B (foliar fertilization), planting material with a larger root collar diameter was obtained using the Megafol growth stimulator – 4.3 mm, which is 0.8 mm more than the control options (3.5 mm).

Conclusions

In the Left Bank Forest-Steppe (Sumy region), *Quercus robur* L. is the main tree species, occupying a significant area of forests in fresh oak forests. However, in typical forest vegetation conditions of the region, especially in fresh oak forests, natural seed regeneration of oak occurs extremely rarely. Therefore, regeneration of oak forests is carried out mainly by creating partial forest cultures, which involves the artificial introduction of woody plants and active silvicultural care for their growth over a long period.

Studies have shown that growing holm oak seedlings with a closed root system (CRS) has significant advantages compared to the traditional method of growing with an open root system (ORS). Seedlings obtained in polyethylene bags demonstrated significantly higher growth and development indicators. Their height reached 35.7 cm, which was 4.4 cm higher than the control samples. The trunk diameter of these plants was also maximum (6.1 mm), and the mass of annual plants was 7.5 g, which is significantly higher than that of the control samples (4.4 g). The weight of the root system of seedlings with CRS in polyethylene bags was also higher (4.8 g) compared to seedlings with CRS (2.8 g) and seedlings with CRS in cassettes (3.9 g).

Growing seedlings in cassettes also contributed to better growth and development compared to the control group, although less pronounced than in polyethylene bags. The height of seedlings in cassettes was 32.4 cm, the stem diameter was 5.2 mm, and the plant weight was 6.2 g.

The study also found that planting material with CRS has a higher survival rate (86.7 %) compared to planting material with ORS (81.5 %). Treatment of planting material with the growth stimulator Megafol helped increase survival to 88.3 %.

Foliar feeding with Megafol had a positive effect on the height of the planting material, increasing it on average to 26.0 cm. The lowest were the seedlings on the control variants (without the introduction of growth stimulants) – 18.4 cm.

The height gain of common oak in 1-year-old forest cultures was significantly greater when they were created by seedlings with CRS (11.6 cm) compared to seedlings with ORS (9.2 cm). The use of the growth stimulant Megafol contributed to an increase in height gain for both seedlings with CRS and ORS.

The root collar diameter was also larger in planting material with CRS (4.10 mm) compared to planting material with ORS (3.72 mm). The use of the growth stimulator Megafol contributed to an increase in the root collar diameter to 4.3 mm.

The optimal time for sowing holm oak acorns was spring. Spring sowing provided higher soil germination (85.2 %), better plant survival (78.7 %), greater seedling height (26.8 cm), larger overall linear dimensions (trunk and root), greater plant weight (6.5 g), larger root collar diameter (0.32 cm), and higher nitrogen content (44.9 SPAD units) compared to autumn sowing.

Therefore, growing holm oak seedlings with a closed root system, especially in polyethylene bags, is an effective method of restoring oak forests in the Left Bank Forest-Steppe. This method provides better plant growth and development indicators, higher survival rate and greater resistance to adverse conditions. The use of growth stimulants, such as Megafol, also helps to improve the growth indicators and survival rate of seedlings. The spring sowing period of acorns is optimal for obtaining better results.

Suggestions

In the Left-Bank Forest-Steppe of Ukraine (Sumy region) to increase the adaptation of *Quercus robur* L. seedlings to forest vegetation conditions, it is recommended to use seedlings with a closed root system. Such seedlings can be grown both in cassettes and in plastic bags. The choice of method is determined by the prospects for mechanization of production and minimization of manual labor.

It is optimal to plant acorns in the spring, which contributes to the formation of seedlings with better morphological, weight and physiological indicators. This, in turn, determines their successful adaptation in forest cultures in the Left-Bank Forest-Steppe of Ukraine.

Additionally, to improve seedling survival and growth, it is recommended to treat woody plants after the appearance of true leaves with the growth stimulator Megafol at a rate of 2 l/ha.

Key factors for successful cultivation of common oak in the conditions of the Left-Bank Forest-Steppe of Ukraine:

• Use of seedlings with a closed root system.

• Spring sowing of acorns.

• Treatment of plants after the appearance of true leaves with the growth stimulator Megafol at a rate of 2 l/ha.

Following these recommendations will contribute to obtaining high-quality planting material and creating productive holm oak plantations in the conditions of the Left-Bank Forest-Steppe of Ukraine.

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