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Influence of winter storage methods of acorns on the development and growth processes of common oak

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Abstract. The economic value and biological stability of common oak stands (*Quercus robur* L.), grown from acorns is substantially higher in comparison with plantings of undergrowth origin.

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Therefore, the cultivation of acorn oak stands is relevant and promising, especially where there is no natural restoration of oak. The purpose of the study was the improvement of seed production technology and cultivation of high-quality planting material of common oak seeds with various methods of winter storage to expand the area of oak forests. In the course of the study, forest-cultural (determination of quality indicators of acorns, planting material, and forest cultures), biometric (determination of growth indicators and mass of planting material), and classical statistical research methods were used. The study was conducted on the territory of the forest fund of the Hertsaevsky state special Forestry and Kuzmynsky Forestry branches of "Chernivtsi Forestry" of the state specialised economic enterprise "Forests of Ukraine". It is shown that each of the winter storing methods of acorns of common oak has its own advantages and disadvantages, which are more or less manifested in different methods of cultivation. As a result of comparing the influence of different cultivation methods on the development of common oak plants grown from seeds stored in a trench method, it was determined that the best growth parameters of the aboveground part of plants were observed when using the larding method. However, the least intensive development of the root system was observed when growing oak with a closed root system. It was found that the weighted average biometric indicators of the growth processes of common oak plants grown from seeds that were stored in tap water were the highest when growing acorns by larding. It is proved that the experimental plants of common oak grown from seeds that were stored in a cellar with sand lagged behind in the development of the aboveground part when grown by a landing method. It was established that the root system developed worse when growing plants with an open root system. The proposed acorn storage technology can be applied to improve the efficiency and quality of reproduction of oak stands by forestry enterprises in Ukraine

Keywords: *Quercus robur* L.; seed material; seedlings; root system; aboveground part; reforestation

Introduction

The main task of forestry activities on the territory of Ukraine is to obtain high-quality wood raw materials. When performing this task, both economic and typological features of forest stands, as well as microclimatic and soil-hydrological features of a particular region are fully considered. Therewith, during the process of growing seed and planting material of the main types of forest-forming woody plants, such as Scots pine (*Pinus sylvestris* L.) and common oak (*Quercus robur* L.), usually, only at an early age the negative impact of environmental factors on plants is considered. Subsequently, at the age of 5-6 years, they die en masse, in particular, due to natural selection and the lack of effective preventive and active extermination protection measures (Bilous, 2016; Kulbanska *et al.*, 2023). For this reason, Z.W. Beer *et al.* (2017), S. Bilous *et al.* (2023) note in their papers that even at an early age, it is necessary to start taking care of a healthy generation of the forest, in particular at the stage of harvesting and storing seed material.

According to S. Sydorenko *et al.* (2021), R.V. Hurzhii *et al.* (2021), increasing the forest cover of the territory in all forest-growing zones of the country by creating additional areas of artificial forest stands has always been the priority area of Forestry in Ukraine, which is possible only if a sufficient amount of high-quality seed and planting material is provided for the main forest-forming species of woody plants. Authors P. Baldi & N. La Porta (2017), L. Gathercole *et al.* (2021) in their study argue that in

the process of growing high-quality seed and planting material, it is extremely important to combine and optimise all elements of the production process: the use of high-quality seeds, the selection of safe storage methods, reasonable standards, and seeding schemes (Jiang *et al.*, 2019), improving the physical and chemical properties of the soil (Kulbanska *et al.*, 2021; Matsiakh *et al.*, 2021), the use of preventive and extermination protection measures in pest, pathogen, and weed control (Brady *et al.*, 2017; Kulbanska *et al.*, 2021), the application of mineral composite fertilisers and growth regulators (Nones *et al.*, 2022), etc.

R.A. Sitz *et al.* (2018), J. Doonan *et al.* (2019) described that the life biological cycle of oak stands alternates between periods of accelerated dying-off and stabilisation of the sanitary condition. Notably, researchers have established a certain chronology and noted the cyclicity of this natural phenomenon. In general, over the past 100 years, three periods of digression can be distinguished, as a result of which there was a massive weakening and dying off of oak: 1927-1946, 1964-1983, and 1982-1911. In particular, during the period of mass degradation of oak forests in the 70s of the 20th century, forest cultures that were planted in a permanent place of forest plots by seedlings (Grünwald *et al.*, 2008; Kulbanska *et al.*, 2021). Therewith, oak cultures that were sown from acorns were determined to be much more resistant to the influence of climatic and other environmental factors. Thus, forest oak cultures can be created both by sowing acorns and planting seedlings. In forest-growing conditions with available soil moisture and a sufficient amount of precipitation, forest oak cultures can be laid in a permanent place of forest plots by planting seedlings. Y. Li *et al.* (2014), S. Liu & Y. Tang (2016) noted that when creating forest oak cultures on dry soils or in an area with insufficient precipitation, within all forest zones, it is more appropriate to give preference to sowing acorns. It is possible to form highly productive and biologically resistant oak stands only considering the above conditions for creating forest cultures of common oak.

Common oak can also be restored in a vegetative way, but not always successfully. N.S. Mukhamadiyev *et al.* (2021), S. Bilous *et al.* (2023) proved that sprout plantings are usually characterised by reduced biological resistance and short duration compared to seed plantings, but they begin to bear fruit earlier. oak stumps with a diameter of more than 50 cm practically do not produce growth, but in fresh and moist forest types of conditions, they are sometimes able to form root sprouts. Due to the work already started in Ukraine on forest certification, the European experience of reforestation is being actively introduced into the forestry practice of leading enterprises in the industry. In particular, testing in the production conditions of certain methods and techniques of reforestation inherent in environmentally oriented Forestry is being conducted, namely: focus on the plantation or positive seed production; introduction of narrow-cutting, gradual, and selective methods of logging of the main use; use of sowing seed material (especially autumn) for the formation of artificial forest stands; conducting a forestry complex of works to improve natural renewal, considering such forest-cultural measures as seed sowing and tillage. (Kulbanska, 2021; Bilous *et al.*, 2023). Methods of long-term storage of seeds and cultivation of high-quality seedlings of forest woody plant species are still insufficiently studied, and the characteristics given in the literature are not equivalent and incomplete.

The problem of studying long-term storage of seeds, including oak acorns, remains relevant, despite certain developments of foresters in this area. Thus, it was quite natural to set the goal of the study as such – scientific justification

of the technology of winter storage of acorns of common oak for growing high-quality planting material and improving seed production technology during reforestation of oak stands.

Materials and Methods

The object of the study was the seed potential and planting material of common oak. Accordingly, the subject of the study was the features of seed production technology and the cultivation of high-quality planting material of common oak, obtained by various methods of winter storage of acorns. To grow high-quality planting material and reproduce and expand the area of oak stands in the fall of 2021, 4,500 acorns of common Oa were collected from under the tent of positive ripe high-quality oak stands within the Hertsaivsky state special Forestry and Kuzmynsky Forestry branches of the state specialised economic enterprise "Forests of Ukraine". Features of the selection of acorns of common oak were conducted under laboratory conditions according to the Resolution of the Cabinet of Ministers of Ukraine No. 977 "On Approval of the State Programme "Forests of Ukraine" for 2002-2015" (2009).

The corresponding acorns were selected and calibrated so that they were the same size and quality characteristics. The dimensions were measured using a calliper with a permissible deviation in diameter ±0.1 mm and a length of ± 0.5 mm. The next step was to divide the acorns into three parts (1500 acorns each): the first was stored in a cellar in the sand, observing the level of its moisture capacity at the level of 60-65% TM (total moisture capacity), the second – in a trench in a conventional way and the third – in tap water. In April, after winter storage, acorns of common oak were examined, measurements, weighing, and a comparative empirical analysis of storage was conducted. The next stage was the preparation of the soil and sowing acorns of common oak in the ground. Acorns were sown on the territory of a temporary nursery of the Kuzmynsky Forestry district. Three methods of growing oak seedlings were used: with an open root system, a closed root system, and the larding method.

After the analysis of acorns, conditions were created for sowing and growing 1,500 seedlings with an open root system in the sowing unit of the nursery in the open ground. In the first decade of May 2021, 1500 pcs. of acorns were sown in ten rows 75 m long, each, after 1 m, with a row spacing of 0.5 m. Therewith, seedlings aged half a year with a closed root system were sown and grown in a greenhouse in the amount of 1590 pcs., in containers sized 30×53 with a pre-sifted soil mixture in the proportions of 33.3% chernozem, 33.3% sand, 33.4% mycorrhiza soil collected from under the canopy of oak stands. Thus, 1500 pcs. of acorns were sown and were grown, from larded acorns on a forest-cultivated area on a plot with no natural restoration of common oak.

Thus, the main research methods for performing this experiment were forest-cultural – to study the technology and methods of winter storage of acorns of common oak; biometric – to determine the biometric indicators of common oak plants grown with different methods of winter storage of acorns; classical statistical – to analyse and process the results obtained, graphic – to identify trends, patterns of analytical dependencies.

Results and Discussion

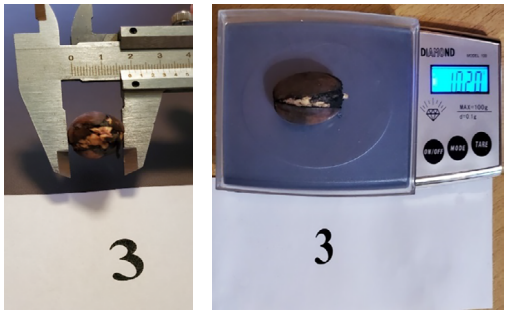
Analysis based on the results obtained (Fig. 1), allows assuming that in acorns that were stored in the trench in winter, the state of forced dormancy is longer than in other samples since the so-called root of the future plant barely hatched and the seeds accumulated moisture to a lesser extent (this is evidenced by the germination rate of plants). The acorn seedling, which was stored in a trench above the soil level of the container,

was visualised only on the seventh day of the experiment, in contrast to the acorn seedling, which was stored in tap water, which showed germination on the third day after sowing.

The results of this experiment are presented in the form of a table (Table 1).

a – after storage in the cellar in the sand

b – after storage in the trench



c – after storage in tap water

Figure 1. Results of winter storage of acorns of common oak

Note: a – storage in a cellar in the sand; b – storage in a trench; c – storage in tap water

Table 1. Analysis of plants of common oak aged half a year grown with different methods of winter storage of acorns

Methods of growing common oak	Total mass, g	Aboveground part		Root system		Diameter near the roots, mm
		height, cm	weight, g	length, cm	weight, g	
After the trench storage method						
with the ORS	173 ± 0.65	31.22 ± 2.22	1.12 ± 0.25	25.22 ± 1.95	2.34 ± 0.40	3.33 ± 0.77
with the CRS	372 ± 1.80	25.8 ± 1.01	0.98 ± 0.51	16.26 ± 0.50	6.46 ± 1.29	4.3 ± 0.89
larding method	273 ± 1.98	32.05 ± 2.35	1.78 ± 0.68	26.05 ± 2.10	3.68 ± 1.30	3.95 ± 0.87
After storage in tap water						
with the ORS	209 ± 0.55	32.42 ± 2.31	1.15 ± 0.20	28.64 ± 2.06	3.03 ± 0.35	2.87 ± 0.70
with the CRS	405 ± 2.05	32.2 ± 1.,00	1.34 ± 0.50	17.84 ± 0.45	6.76 ± 1.55	4.4 ± 0.95
larding method	779 ± 2.50	33.0 ± 2.40	3.03 ± 1.20	43.0 ± 2.15	12.55 ± 1.40	5.4 ± 2.00

Table 1, Continued

After storage in a sand cellar						
with the ORS	220 ± 0.60	28.42 ± 1.70	1.0 ± 0.20	26.42 ± 1.20	3.40 ± 0.40	3.32 ± 0.76
with the CRS	324 ± 1.72	28.28 ± 1.56	1.02 ± 0.57	16.72 ± 0.50	5.46 ± 1.14	4.54 ± 0.92
larding method	262 ± 0.65	24.0 ± 2.02	0.94± ± 0.21	41.0 ± 1.41	4.30 ± 0.43	3.9 ± 0.85

Note: ORS – open root system; CRS – closed root system
Source: ccompiled by the authors

Analysis of the examination of weighted average biometric indicators, in particular, the total mass, height and mass of the aboveground part, the length and mass of the root system, and the diameter at the root neck of the plants aged half a year of common oak grown by various methods allows stating that each of the winter methods of storing oak acorns has its own advantages and disadvantages. Notably, the highest parameters of common oak seedlings were obtained by the method of storing acorns in tap water and larding: the indicator "total mass" (g) is 779 ± 2.50, the indicator "height of the aboveground part" (cm) is 33.0 ± 2.40, the indicator "mass of the aboveground part" (g) is 3.03 ± 1.20, the indicator "length of the root system" (cm) is 43.0 ± 2.15, the indicator "mass of the root system" (g) is equal to 12.55 ± 1.40, the indicator "diameter at the root neck" (mm) is 5.4 ± 2.00. The lowest parameters of common oak seedlings are noted when storing acorns in a cellar with sand with an open root system: the indicator "total mass" (g) is 220 ± 0.60, the indicator "height of the aboveground part" (cm) is 28.42 ± 1.70, the indicator "mass of the aboveground part" (g) is 1.00 ± 0.20, the indicator "length of the root system" (cm) is 26.42 ± 1.20, the indicator "mass of the root system" (g) is equal to 3.40 ± 0.40, the indicator "diameter at the root neck" (mm) is 3.32 ± 0.76. The influence of cultivation methods on the development of common oak plants grown from seeds that were stored in different ways is also analysed and presented in the form of graphs (Fig. 2, 3, and 4).

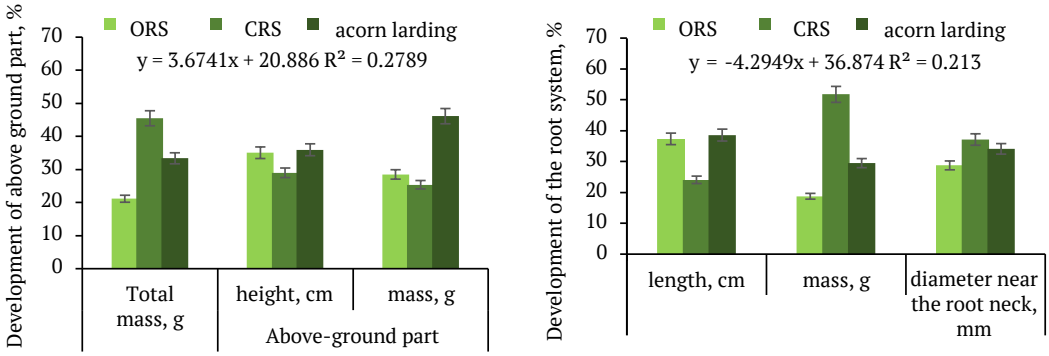


Figure 2. Development of common oak plants after trench winter storage of acorns with different cultivation methods, %

Note: ORS – open root system, CRS – closed root system
Sourse: compiled by the authors

Having analysed the influence of cultivation methods on the development of common oak plants grown from seeds that were stored by trench method, the best growth parameters

of the aboveground part of plants were observed when growing by larding (the indicator "height" (cm) is 32.05 ± 2.35, the indicator "weight" (g) is 1.78 ± 0.68), and the development of the root system was the least intensive when growing oak with a closed root system (the indicator "length" (cm) is 16.26 ± 0.50, the indicator "the mass" (g) is 6.46 ± 1.29). Therewith, experimental plants of common oak lagged behind in growth in all experimental parameters when growing plants with an open root system.

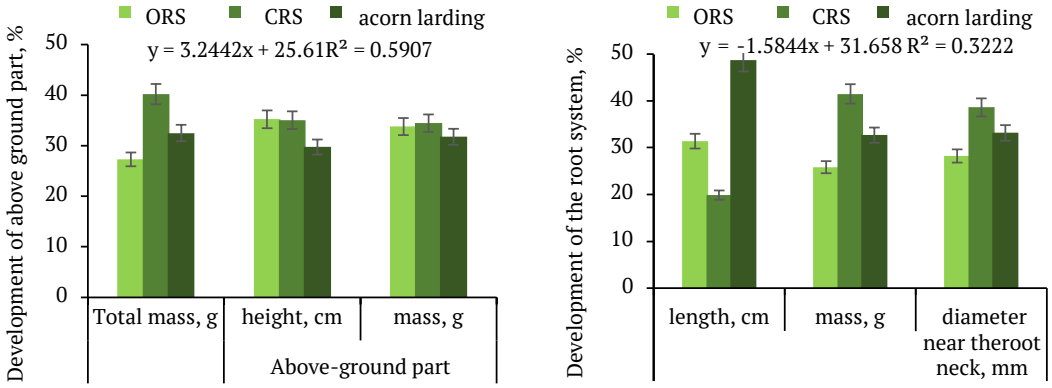


Figure 3. Development of common oak plants after storing acorns in tap water using different methods of cultivation, %

Note: ORS – open root system, CRS – closed root system
Sourse: compiled by the authors

Analysing the influence of various cultivation methods on the development of common oak plants grown from seeds that were stored in tap water, it was noted that the best growth parameters of the aboveground part (the indicator "height" (cm) is 33.0 ± 2.40, the indicator "mass" (g) is 3.03 ± 1.20) and the root system of plants (the indicator "length" (cm) is 43.0 ± 2.15, the indicator "mass" (g) is 12.55 ± 1.40) were observed when growing acorns by larding. Therewith, experimental plants of common oak lagged behind in growth in all experimental parameters when growing plants with an open root system.

Analysing the influence of various cultivation methods on the development of common oak plants grown from seeds that were stored in a cellar with sand, it is noted at the best growth parameters of the aboveground part and the root system of plants were observed when growing by the method with a closed root system. Therewith, the experimental plants of common oak lagged behind in the development of the aboveground part (the indicator "height" (cm) is 24.0 ± 2.02, the indicator "mass" (g) is 0.94 ± 0.21) when grown by larding, and the root system (the indicator "length" (cm) is 26.42 ± 1.20 the indicator "mass" (g) is 3.40 ± 0.40) developed worse when growing plants with an open root system.

Good quality of common oak seeds in forest stands of Ukraine, according to researchers V.M. Bilous (2016), Z. Moussa *et al*. (2021), is approximately 45% in harvest years and substantially depends on abiotic and biotic environmental factors, and on the influence of endophytic and epiphytic microbiota (Moradi-Amirabad *et al*. 2019; Kulbanska *et al.*, 2021). In addition, germination is affected by the

supply of nutrients in acorns. This was most evident in this study when storing acorns in tap water. Absorbing water, acorns increased their size and their upper crust was broken. In addition, the water transferred nutrients to the state in which they were involved, while the water reduced the seed dormancy of acorns. According to G.O. Boyko & O.V. Bashta (2015), seed germination rate and other quality indicators are largely influenced by the storage method. Ultimately, even under optimal conditions in the process of respiration (metabolism), the spare nutrients of seeds are gradually consumed without their subsequent intake, the solubility of protein substances decreases, as a result of which the mass of seeds decreases, and therefore – the germination rate. High humidity and temperature, on the one hand, enhance the processes of metabolism, that is, the weakening of seeds, and on the other – contribute to the development and change of the ratio of saprotrophic and pathogenic microflora and forest conditions, which substantially affect the quality indicators of seeds.

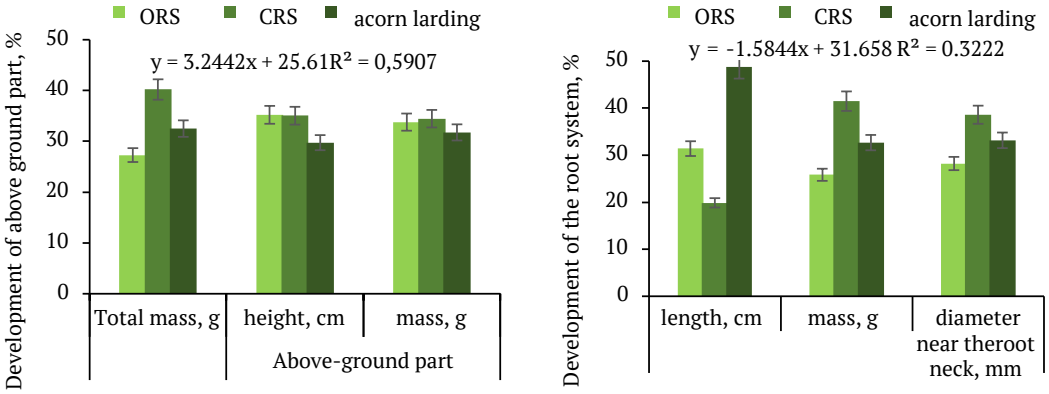


Figure 4. Development of common oak plants after storing acorns in a sand cellar using various methods of cultivation, %

Note: ORS – open root system, CRS – closed root system
Sourse: compiled by the authors

Researchers G.O. Boyko, & N.V. Puzrina (2015) established that the dark-seeded form of Scots pine is promising for sowing since it is least populated with harmful microorganisms during storage and has the highest qualitative and quantitative indicators. According to S. Nones *et al.* (2022), a substantial impact on the quality of acorns and deterioration of storage cause damage – microtrauma with intoxication and mechanical damage to the embryo or shell in the embryo area. They divide the source of injury into two groups. The first category includes environmental factors and morphological features of the plant – this is the lesion of seeds by microorganisms, pests, and early autumn frosts. In the course of this study, acorns that had black, bluish-black, or other spots on cotyledons, especially the germ circle, which occupied more than a third of the entire cotyledon and acorns that did not sink badly in water, were of poor quality. Thus, in the general analysis, it can be argued that a large weight and germination rate affect the quality of sproutings and is one of the signs of high seed quality. It is also known that acorns of common oak are a good food product for

wild and domestic animals, which is why the number of quality acorns on the soil surface is substantially reduced. Similar studies were also conducted by such researchers as: N.M. Voloshchuk & V.M. Bilous (2012), V.M. Bilous (2016). Therewith, systematic studies on the method of winter storage of acorns and the impact on development and growth processes have not been fully conducted.

The totality of organisational and technological errors made in the past when harvesting and storing seed material, planting, and laying woody plants and plantings of various purposes are undoubtedly the root causes of the deterioration of their sanitary condition in the future. Therefore, the study of the influence of winter storage methods of acorns on the development and growth processes of common oak is now a promising area of research and an important urgent Forestry problem that requires further thorough research and analysis of the results obtained.

Conclusions

After analysing the data obtained during the study, it was concluded that each of the winter methods of storing acorns of common oak has its own advantages and disadvantages, which are more or less manifested with different methods of cultivation. However, comparing the influence of different cultivation methods on the development of common oak plants grown from seeds that were stored by trench method, it was noted that the best growth parameters of the aboveground part of plants were observed when growing by larding (the indicator "height" (cm) is 32.05 ± 2.35, the indicator "weight" (g) is 1.78 ± 0.68), and the development of the root system was the least intense when growing oak with a closed root system (the indicator "length" (cm) is 16.26 ± 0.50, the indicator "mass" (g) is 6.46 ± 1.29). Weighted average biometric indicators of growth processes of common oak plants grown from seeds that were stored in tap water were the highest when growing acorns by the larding method, in particular, the following parameters of the aboveground part (indicator "height" (cm) is 33.0 ± 2.40, indicator "mass" (g) is 3.03±1.20) and the root system of plants (indicator "length" (cm) is 43.0 ± 2.15, indicator "mass" (g) is 12.55 ± 1.40). Therewith, experimental plants of common oak grown from seeds that were stored in a cellar with sand lagged behind in the development of the aboveground part (the indicator "height" (cm) is 24.0 ± 2.02, the indicator "mass" (g) is 0.94 ± 0.21) when grown by the larding method, and the root system (the indicator "length" (cm) is 26.42 ± 1.20 the indicator "mass" (g) is 3.40 ± 0.40) and developed worse when growing plants with open the root system. The results of the conducted experiments indicate the timeliness and expediency of using the examined methods of winter storage of acorns to intensify the development and growth processes of common oak and their further use in reforestation and afforestation. In the future, it is advisable to examine the further growth of acorns depending on the geographical environment, that is, on a certain combination of external factors – climate and soil, and the action of various growth stimulators. This will allow growing oak cultures more efficiently in the future.

Conflict of Interest

None.

Acknowledgements

None.

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Вплив способів зимового зберігання жолудів на розвиток та ростові процеси дуба звичайного

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Анотація. Господарська цінність та біологічна стійкість насаджень дуба звичайного (*Quercus robur* L.), вирощених із жолудів є вагомо вищою у порівнянні із насадженнями порослевого походження. Тому, актуальним та перспективним є вирощування дубових насаджень із жолудів, особливо там, де відсутнє природне відновлення дуба. Метою дослідження було удосконалення технології насінництва та вирощування високоякісного садивного матеріалу дуба звичайного насінням при різних способах зимового зберігання для розширення площ дубових лісів. Під час наукового дослідження використано лісокультурні (встановлення показників якості жолудів, садивного матеріалу та лісових культур), біометричні (визначення показників росту та маси садивного матеріалу), та класичні статистичні методи дослідження. Дослідження проводили на території лісового фонду Герцаївського держспецлісництва та Кузьмінського лісництва філії «Чернівецьке лісове господарство» державного спеціалізованого господарського підприємства «Ліси України. Показано, що кожен із зимових способів зберігання жолудів дуба звичайного має свої переваги і недоліки, які у більшій чи меншій ступені проявляються при різних методах

вирощування. В результаті порівняння впливу різних методів вирощування на розвиток рослин дуба звичайного, вирощеного із насіння, що зберігалося траншейним способом, було встановлено, що найкращі ростові параметри надземної частини рослин спостерігалися при використанні методу шпигування. Проте, найменш інтенсивний розвиток кореневої системи спостерігався при вирощуванні дуба з закритою кореневою системою. Виявлено, що середньозважені біометричні показники ростових процесів рослин дуба звичайного, вирощеного із насіння, яке зберігалося у проточній воді, були найвищими при вирощуванні методом шпигування жолудів. Доведено, що дослідні рослини дуба звичайного, вирощеного із насіння, яке зберігалося у погребі із піском відставали у розвитку надземної частини при вирощуванні методом шпигування. З'ясовано, що коренева система розвивалась найгірше при вирощуванні рослин із відкритою кореневою системою. Запропонована технологія зберігання жолудів може бути застосована для підвищення ефективності та якості відтворення дубових насаджень лісогосподарськими підприємствами України

Ключові слова: *Quercus robur* L.; насіннєвий матеріал; сіянці; коренева система; надземна частина; лісовідтворення