# PECULIARITIES OF CULTIVATING *ACER PLATANOIDES* L. PLANTING MATERIAL UNDER THE CONDITIONS OF THE NORTH-EASTERN FOREST-STEPPE OF UKRAINE

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Forests play a fundamental role in maintaining ecological equilibrium, regulating climate, and ensuring the socio-economic well-being of society. They occupy approximately 16 % of the territory of Ukraine; however, this indicator remains below the optimal level for a temperate climate (25–30 %), indicating a necessity for expanding forest areas, particularly through the establishment of highly productive stands [4].

According to estimates, one hectare of mature forest sequesters an average of 10–12 tons of $CO_2$ annually, rendering forest plantations a key instrument in mitigating climate change [31, 33, 38].Highly productive stands ensure not only economic benefits but also long-term ecological stability. In such forests, the annual wood increment can reach 6–8 $m^3$/ha, which is twice the average indicators for natural forests in the Polissia and Forest-Steppe regions of Ukraine. They serve as the foundation for continuous forest management, carbon stock formation, and soil protection against erosion. Research results indicate that the creation of highly productive pine cultures with an admixture of deciduous species increases the growing stock by 15–20 % compared to monocultures of the same age [42].

The relevance of afforestation in Ukraine is driven by the need for eco-adaptive forest restoration, which serves as the primary method for increasing the state's forest cover under conditions of global anthropogenic landscape transformation [16]. The establishment of new forest massifs requires a scientifically justified selection of species that correspond to specific forest-growing conditions and ensure maximum ecological impact. In this context, an important aspect involves modeling the optimal carbon accumulation specifically in mixed, uneven-aged forests, where the structural complexity of the phytocenosis allows for a stable balance between carbon sequestration and biomass productivity [1].

Special attention should be given to the role of mixed stands. Traditionally, pure forests – pine, oak, or spruce monocultures – predominated in Ukraine. However, contemporary research demonstrates that they are less resilient to climate change, pests, and windthrows. In contrast, mixed forests form a more complex structure, ensuring a more uniform microclimate and a more stable soil cover. The mixing of species enhances resource-use efficiency, particularly concerning water and nutrients, which positively influences biomass productivity [5, 14].

Mixed forests involving broad-leaved species such as common oak (*Quercus robur*), Norway maple (*Acer platanoides*) and small-leaved lime (*Tilia cordata*) contribute to the improvement of the physicochemical properties of the soil. Studies show that the organic matter content in the upper soil layer under mixed stands is 20–25 % higher than under pure pine cultures, creating favorable conditions for the development of mycorrhiza and microflora. This, in turn, enhances natural fertility and reduces the requirement for fertilizer application [23].

In addition to improving soil conditions, the incorporation of companion species into shelterbelts and forest strips is of critical importance for modern apiculture. In particular, the nectar and pollen potential of woody species such as maple and linden provides a stable forage base for entomofauna, thereby contributing to increased crop yields in adjacent agricultural landscapes [35]. Thus, mixed forest stands function as biological reservoirs, supporting the activity of natural pollinators within the Forest-Steppe zone.

Norway maple, although not classified as a principal forest-forming species, plays a significant ecological and bioengineering role within mixed forest ecosystems. Its root system enhances soil stabilization and prevents erosion processes, while its dense canopy contributes to the formation of a stable microclimate beneath the forest cover. Moreover, maple serves as an additional nectar source for pollinators and provides habitat for invertebrates and avifauna. Empirical data indicate that in pine–maple stands, understory biodiversity is approximately 30 % higher than in pure pine stands of the same age [20, 32].

From an economic perspective, the admixture of broadleaved species in coniferous plantations improves timber quality and reduces the risk of simultaneous stand mortality due to pests or wildfires. For example, in mixed stands, the proportion of pest-damaged trees is 40 % lower compared to pure pine forests. This effect can be attributed to the "resource dilution" phenomenon in pest trophic bases and the enhanced moisture-retention capacity of the understory [49].

From an organizational and economic standpoint, the planning of such forest establishment is not feasible without the development of a network of permanent nurseries. The design and implementation of plans for specialized ornamental and forest nurseries, particularly within individual forestry enterprises, ensure the production of high-quality planting material with predictable survival rates [30]. This creates a reliable foundation for large-scale afforestation and land reclamation programs.

In addition to increasing resilience, the inclusion of broadleaved species contributes to the stabilization of the soil nitrogen balance. The litter of maple and linden decomposes more rapidly, enriching the upper soil horizons with bioavailable forms of nitrogen and potassium, which is particularly important for young pine stands on sandy soils. Field studies have shown that the introduction of 10–15 % share of maple increases the average annual increment of pine by 8–12 %, due to improved nitrogen nutrition and soil moisture retention [13].

Highly productive mixed stands also demonstrate a greater capacity for carbon sequestration. Studies indicate that forests composed of three or more tree species contain 25–30 % higher carbon stocks in aboveground biomass compared to monocultures of the same age class. This underscores the importance of mixed forest establishment as a key component of Ukraine's national climate strategies. Specifically, increasing the proportion of mixed stands by 10 % may result in an additional sequestration of approximately 1.8 million tons of $CO_2$ annually [8, 44].

The study of biomass accumulation mechanisms shows that mixed stands are better adapted to water stress conditions. In the context of climate change, the ability of maple and other broadleaved species to maintain optimal soil water regimes becomes critical for the survival of the coniferous component. Research confirms that the resource-use efficiency of such ecosystems increases due to niche differentiation among root systems of different tree species [14, 29].

Equally important is the aesthetic and recreational value of such forests. Mixed stands exhibit more pronounced seasonal color dynamics and create an attractive environment for public recreation [41]. According to sociological surveys, 68 % of respondents prefer mixed forests over monocultures, indicating the potential for integrating productive and cultural functions of forests in contemporary forest management [28, 24, 41].

The aesthetic appeal of mixed forests is also closely associated with the psychological comfort of visitors in urbanized areas. The establishment of park zones using various maple species enables the creation of landscapes with high chromatic diversity during the autumn period, positively influencing the recreational evaluation of urban green spaces [24]. This highlights the necessity of integrating silvicultural approaches into urban planning.

In conclusion, the establishment of highly productive mixed forest stands, incorporating not only principal but also auxiliary species such as Norway maple, represents a strategic direction for the development of Ukraine's forestry sector [18]. The combination of coniferous and broadleaved species ensures an optimal balance between productivity, resilience, and ecological stability of forest ecosystems. Such an approach aligns with contemporary principles of sustainable forest management and contributes to the formation of long-lived, climate-adapted forests for future generations [19].

The analysis of long-term experience in the cultivation of mixed forest stands indicates that the success of reforestation is directly dependent on the quality of the seed material used and the technologies applied for its pre-sowing treatment [3, 11]. The application of modern seedling growth intensification techniques in combination with mycorrhization creates favorable conditions for the formation of resilient forest ecosystems of the future. The implementation of innovative solutions in forest nursery practices is a key prerequisite for achieving the target forest cover indicators of Ukraine [30, 45].

Maples (*Acer spp.*) occupy an important niche in the forest ecosystems of Ukraine, particularly Norway maple, sycamore maple (*Acer pseudoplatanus*), and field maple (*Acer campestre*). Although they are not classified as principal forest-forming species, their share in the overall forest composition of the country reaches 3–5 %. In the Forest-Steppe zone and the Carpathians, maples constitute an essential component of mixed stands. They play a significant ecological role in stabilizing forest ecosystems by improving soil properties, contributing to understory formation, and supporting biodiversity conservation [48, 15].

From an ecological perspective, maple species play a substantial role in maintaining soil fertility. Their leaf litter decomposes rapidly, forming humus that enriches upper soil horizons with organic compounds of nitrogen, calcium, and potassium. Studies have shown that soils under maple stands contain 25–30 % higher humus content compared to pure pine plantations. Consequently, maple functions as a natural "biofertilizer," enhancing soil structure and permeability [7, 9].

Norway maple is characterized by high shade tolerance and frost resistance, making it an effective component of mixed forests in the northern Forest-Steppe zone. Its deep root system contributes to soil stabilization, preventing erosion on slopes and in riparian areas. Research conducted by Ukrainian forestry scientists has demonstrated that the inclusion of 10–20 % maple in pine stands increases their resistance to windthrow by 15–18 % and reduces drought-related losses [46].

One of the key aspects of maple's ecological significance is its influence on the microclimate of forest ecosystems. Due to its dense canopy, it provides shading and reduces the temperature beneath the forest canopy by 2–4°C, which positively affects understory growth and soil moisture conservation. In mixed stands containing maple, soil surface evaporation is reduced by up to 20 %, which is particularly important for forests in the Forest-Steppe zone with a moderately continental climate [7].

Maple also holds considerable economic value due to the favorable physical and mechanical properties of its wood. It is hard, dense, fine-textured, and exhibits a light luster, making it a valuable raw material for the production of furniture, musical instruments, parquet flooring, and decorative elements. Its bending strength exceeds that of pine by 30–35 %, and its hardness by approximately 40 % [10, 25]. In Ukraine, maple wood is widely utilized in the furniture and plywood industries, particularly in the Volyn, Lviv, and Cherkasy regions.

In addition to its industrial importance, maple stands play a vital role in sanitary-protective and recreational afforestation. Maple effectively absorbs dust and nitrogen oxides from the air, contributing to the purification of urban ecosystems. One hectare of maple plantation can absorb up to 80 kg of dust and 40 kg of gaseous pollutants annually. For this reason, maple is widely used as a principal species in the establishment of green belts around cities and along transportation corridors [28].

Its importance as a melliferous plant is also well recognized. The flowering of Norway maple provides early spring nectar, supporting pollinator populations after winter dormancy. One hectare of flowering maple forest can yield up to 100 kg of nectar, making it an important component of ecological networks within agricultural landscapes. This integration of forestry and apiculture enhances biodiversity and promotes the sustainable use of natural resources [17].

Within mixed stands, maple also functions as a biological "buffer" species for the main tree components. It mitigates environmental stresses by creating more stable growth conditions for coniferous species. In pine–maple stands, for instance, a more balanced soil water regime is observed, reducing the risk of seedling mortality during drought years. Studies have shown that the inclusion of broadleaved species in coniferous stands increases overall forest productivity by 10–25 % [22].

Furthermore, maple plays an important role in the conservation of genetic resources and ecosystem stability. Its seeds are effectively dispersed by wind, facilitating natural regeneration on clear-cut areas and forest gaps. This trait allows maple to be used as a pioneer species in the reclamation of degraded lands and in the establishment of protective forest belts. It has been documented that on technogenically disturbed soils, the survival rate of maple seedlings exceeds 85 %, surpassing that of oak and ash [50].

Within the complex of national economic functions, maple forests and their admixtures possess long-term economic and ecological value. They contribute to ecosystem stability, enhance the productivity of dominant species, improve soil and air quality, and contribute to the aesthetic value of natural landscapes. In the long term, maple must remain one of the key associate species within the structure of mixed stands, particularly in programs aimed at adapting Ukrainian forestry to climate change [26].

The cultivation of high-quality Norway maple planting material is a critical prerequisite for the successful establishment of mixed and protective forest stands. Given that this species is characterized by slow initial growth, the precise selection of sowing dates, seed placement depth, and the application of fertilizers and growth regulators significantly influence seedling survival rates and the formation of a robust root system [11, 21].

Seeds of Norway maple exhibit a deep dormancy period lasting 4–6 months. To obtain uniform germination, stratification is required, involving the storage of seeds in moist sand at a temperature of +2 to +5°C for 90–120 days. Field experiments have demonstrated that cold stratification increases germination rates from 42 % to 88 %, while seedling emergence occurs 10–12 days earlier compared to non-stratified control variants [27, 44].

Regarding sowing time, the best results are achieved with autumn or early spring sowing. Autumn sowing (October–early November) allows seeds to undergo natural stratification in the soil, resulting in uniform emergence in spring. However, in the absence of sufficient snow cover, there is a risk of seed frost damage. Therefore, in the northern regions of Ukraine, spring sowing following artificial stratification is preferable. The optimal sowing depth for Norway maple seeds ranges from 2.5 to 4 cm, depending on soil texture. On light sandy soils, seeds are sown deeper (up to 4 cm) to prevent desiccation, whereas on loamy soils, the depth should not exceed 2.5 cm to ensure rapid germination. Burial deeper than 5 cm reduces germination by more than 20 % due to the mechanical difficulty of cotyledon emergence. The optimal seeding density is 5–6 g/m², providing approximately 350–400 seedlings [3].

Soil preparation is a critical factor. Maple exhibits optimal growth on fertile loamy and sandy loam soils with a pH of 6.0–7.0. Prior to sowing, deep plowing (25–30 cm) and cultivation are performed, followed by the application of mineral fertilizers at rates of 40–60 kg/ha nitrogen, 60–80 kg/ha phosphorus, and 40 kg/ha potassium. The application of organic fertilizers (10–15 t/ha of humus) improves soil structure and water-holding capacity [29].

To stimulate seed germination, growth regulators of natural origin are widely used. Pre-sowing treatment with gibberellin solutions (25 mg/L) or succinic acid (100 mg/L) accelerates germination by 5–7 days and increases germination energy by 15–20 %. The use of biostimulants such as “Epin-Extra” or potassium humate promotes better development of the primary root system and reduces sensitivity to moisture fluctuations. On average, seedling survival increases from 78 % to 92 % under such treatments [6, 36, 39].

Seedling care includes regular soil loosening, weed control, and maintenance of optimal soil moisture. During drought periods, irrigation is applied at a rate of 200–250 m³/ha to prevent surface crust formation [29]. To enhance irrigation efficiency, hydrogels–polymeric substances capable of retaining water in the root zone–are used. The application of hydrogels at a rate of 30 kg/ha reduces irrigation frequency by 25–30 % without compromising seedling productivity [45, 36].

Mycorrhization is of particular importance, involving the inoculation of seedling roots with fungi such as *Pisolithus tinctorius* or *Laccaria laccata*. These fungi form symbiotic associations that enhance nutrient availability and increase resistance to pathogens. Studies conducted in the Zhytomyr forestry enterprise have shown that mycorrhization increased the survival rate of Norway maple seedlings from 74 % to 91 %, and the average plant height in the first year from 12.4 cm to 16.7 cm [12, 34, 47].

An additional practice to improve planting material quality is the application of anti-stress growth regulators during transplanting. The use of “Zircon” or “Radifarm” at concentrations of 0.1–0.2 % during transplantation reduces root damage losses by 20–25 %. These treatments facilitate faster adaptation of seedlings to new conditions and stimulate the formation of secondary roots [2, 40].

One year after sowing, seedlings reach an average height of 20–25 cm with a stem diameter of 3–4 mm. In nurseries applying intensive cultivation technologies (irrigation, fertilization, mycorrhization), these parameters may be 30–35 % higher [43]. Seedlings suitable for outplanting are those with a well-developed root system, an unbranched main root, and a height-to-diameter ratio not exceeding 8:1.

Thus, the technology for cultivating Norway maple planting material is based on an integrated approach combining physiological, agronomic, and biotechnological methods. The most critical factors include seed stratification, optimal timing and depth of sowing, application of organo-mineral fertilizers, and the use of growth biostimulants. Adherence to these principles ensures the production of healthy, viable planting stock with survival rates exceeding 90 %, which is a prerequisite for the establishment of resilient, productive, and climate-adapted forest stands [2, 37].

**Research Conditions.** The research was conducted on the basis of the Krasnopillia Forestry Branch of the State Specialized Enterprise “Forests of Ukraine,” which functions as a structural subdivision of the State Enterprise “Forests of Ukraine.” The administrative location of the branch is: 42400, Ukraine, Sumy Oblast, Sumy District, urban-type settlement Krasnopillia, 6 Kalinina Street.

The State Enterprise “Krasnopillia Forestry” occupies a significant position in the economic development of the Krasnopillia district at the present stage. Its history dates back to 1935. The enterprise is territorially located in the eastern part of Sumy Oblast and encompasses lands within the Krasnopillia, Sumy, and Trostianets districts, covering a total area of 23,235 hectares.

Organizationally, the enterprise includes five forest districts, as well as a number of production and auxiliary units. These comprise a wood-processing workshop, a lower timber yard, an in-house vehicle fleet, repair facilities, and an apiary. The principal forest-forming species underpinning forest management activities include oak, ash, maple, and pine. The allowable annual cut for final fellings is established at 36.6 thousand m³. The annual area of clear-cutting operations amounts to 90–100 hectares, while thinning and sanitary fellings are conducted annually over an area of 750–770 hectares.

The average number of employees engaged in the forestry enterprise is 223. Considerable attention is devoted to reforestation and sustainable forest management practices. Annually, new forest plantations are established over an area of 90–100 hectares. To support this process, a permanent nursery with a total area of

8.7 hectares operates within the Velykobobrytske forest district. This nursery produces planting material of key forest-forming species (seedlings of oak, ash, pine, spruce, and linden), as well as a wide range of ornamental plants. Ornamental species include seedlings and saplings of thuja, juniper, boxwood, chestnut, spruce, barberry, and others. Additionally, ground-cover (carpet-forming) plants are cultivated in specialized greenhouses and nursery plots.

Territorially, the branch is located in areas with relatively high forest cover; in the Krasnopillia district, it reaches 24.1 %, with forest stands distributed relatively evenly. The enterprise plays an important role in meeting regional timber demand, satisfying approximately 80 % of local needs. For example, in 2016, more than 53.08 thousand $m^3$ of merchantable timber were harvested, of which over 27.17 thousand $m^3$ constituted industrial wood.

The temperature regime of the Krasnopillia district, located within the Eastern Forest-Steppe zone of Ukraine, is a key ecological factor determining both biological processes (vegetation period, growth intensity) and the agro-technical feasibility of forestry operations. The region is characterized by a moderately continental climate with pronounced seasonality and significant annual temperature amplitudes. The mean annual air temperature typically ranges between 6.5 and 7.5°C, with a tendency toward increase due to global climate change. January is the coldest month, with average temperatures ranging from –6.0 to –8.0°C. Absolute minima may drop to –30°C or lower, posing a risk of frost damage to young, non-adapted seedlings of Norway maple and limiting its cultivation.

The vegetation period, defined by a mean daily air temperature exceeding +5°C, lasts on average 200–210 days, beginning in the first half of April and ending in the second half of October. This period is critical for conducting major operations in forest nurseries and plantations. The sum of active temperatures (above +10°C), which determines photosynthetic activity and biomass accumulation, amounts to approximately 2600–2800°C. This thermal resource is sufficient for the successful production of standard planting material of Norway maple, although it necessitates optimization of sowing dates and the use of growth regulators.

The transition of temperature above +10°C in spring serves as a signal for intensive seedling growth and determines optimal planting periods. Rapid temperature increases in May (mean monthly temperatures reaching +15 to +18°C) promote high survival rates but simultaneously increase the risk of early summer droughts, particularly affecting seedlings with imbalanced root-to-shoot ratios.

The summer period is characterized by average temperatures of +19 to +22°C (July). However, the increasing frequency of extreme temperatures (up to +35°C), combined with low soil moisture, intensifies thermal stress and necessitates the application of drought-resistance-enhancing technologies, including the use of high-quality planting material with increased root collar diameter and optimal root system coefficients.

The autumn period is crucial for seedling hardening prior to winter, involving the accumulation of starch and other protective compounds. Sharp temperature declines in October–November to sub-zero values may damage plants that have not completed vegetation. Therefore, analysis of the temperature regime is fundamental for adapting technological solutions in forestry, particularly in determining optimal application rates of growth regulators.

The moisture regime directly influences soil water balance, plant transpiration intensity, and overall forest ecosystem productivity. The Krasnopillia district, located within a zone of sufficient but unstable moisture in the Eastern Forest-Steppe, is characterized by pronounced seasonal unevenness in precipitation.

The average annual precipitation ranges between 500 and 550 mm, which is theoretically sufficient to meet the needs of forest stands. Approximately 65–75 % of annual precipitation falls during the warm period (April–October), which is favorable for vegetation.

The spring period (April–May) is often characterized by insufficient precipitation, leading to soil moisture deficits at the beginning of the growing season. This is particularly critical for newly planted seedlings, as it slows their establishment and growth. In summer (June–August), precipitation peaks in July but is typically torrential, resulting in high surface runoff and low infiltration rates. Consequently, despite high monthly precipitation totals, a significant portion of water does not remain in the root zone, increasing the risk of soil drought between rainfall events.

To objectively assess moisture conditions, the Selyaninov's hydrothermal coefficient (HTC) is used, representing the ratio of precipitation during periods with temperatures above +10°C to the sum of active temperatures. In the Krasnopillia district, HTC values typically range from 1.0 to 1.2, corresponding to a zone of sufficient moisture. However, the increasing frequency of atmospheric and soil droughts in recent years may reduce HTC values, especially during critical summer months. This necessitates higher requirements for planting material quality, particularly seedlings with a high root-to-shoot ratio to improve water-use efficiency and drought resistance.

The soil cover of the Krasnopillia district, typical of the Eastern Forest-Steppe, is a key edaphic factor determining forest productivity, particularly for Norway maple. The dominant soils are typical chernozems and grey forest soils, formed on loess parent material under moderately continental climatic conditions and alternating meadow and forest vegetation.

Typical chernozems occupy watershed plateaus and exhibit the highest natural fertility. Their main characteristics include a deep humus horizon (up to 70–100 cm), high humus content (4–6 %), and a stable granular structure providing optimal water-air regime. These soils are highly suitable for Norway maple, promoting the development of a strong root system and rapid aboveground growth.

At the same time, significant areas, particularly on elevated relief elements and under long-established forests, are occupied by grey forest soils formed through podzolization processes. These soils are characterized by a thinner humus horizon (30–40 cm) and lower humus content (1.5–3.5 %) compared to chernozems. A distinctive feature is profile differentiation into eluvial (leached) and illuvial (clay-enriched) horizons, often resulting in periodic waterlogging in spring and rapid drying during summer droughts.

On slopes and in ravines, sod-podzolic soils and meadow-chernozem soils may also occur, the latter associated with depressions and characterized by gleyed horizons due to shallow groundwater levels.

From a forestry perspective, the predominantly medium loamy texture of soils in the region is favorable, ensuring adequate water permeability and moisture retention. However, grey forest soils require particular attention, as their tendency toward compaction and temporary waterlogging may adversely affect root system development. Therefore, the implementation of agrotechnical measures aimed at improving soil aeration and structure, along with the use of high-quality planting material capable of withstanding stress conditions associated with soil heterogeneity, is essential for successful afforestation in the Krasnopillia district.

The production of high-quality planting material of Norway maple at the permanent nursery of the Velykobobrytske forest district of the Krasnopillia Forestry Enterprise is an essential component of meeting the silvicultural demands of the enterprise, as maple represents one of the associated species used in forest stand formation. Under Forest-Steppe conditions, where flat (non-ridge) sowing on fertile soils predominates, primary attention is given to proper seed preparation, optimal sowing dates and patterns, enabling maximization of standard seedling output within a single vegetation period.

Considering that the soils of the nursery fields include chernozems and grey forest soils, the pre-sowing soil preparation system is aimed at creating a loose soil layer and preserving moisture. On heavy, compacted plots, deep tillage using moldboardless plowing is required, followed by cultivation and harrowing. To level the surface and break down large soil clods prior to sowing, soil milling using FPSh-1.3 rotary tillers was applied, while light rolling with ZKVG-1.4 rollers was used to ensure soil compaction and facilitate capillary moisture rise.

For sowing, first-class quality seeds are used, which do not require prolonged stratification. Under Forest-Steppe conditions, preference is given to autumn sowing of Norway maple, as seeds sown in autumn undergo natural stratification and produce earlier and more uniform emergence, allowing seedlings to establish before the onset of summer droughts – a critical factor for the region. Seeds are sown in a dry state approximately 1.5–2 months prior to stable soil freezing. In cases where spring sowing is required, seeds must be stratified for 90 days in trenches or storage facilities in a mixture with moist sand. Prior to sowing, treated seeds are disinfected with systemic fungicides approved for forestry use to protect against fungal diseases, particularly fusariosis.

The seeding rate for Norway maple is 12 g per linear meter of furrow. The sowing depth should be maintained within 2–4 cm, which is optimal for relatively large seeds in loamy soils typical of the region and ensures adequate moisture availability. Sowing is carried out manually using a banded three-row patterns, allowing for efficient mechanization of subsequent maintenance operations.

Following emergence, seedlings – being sensitive to late spring frosts – require protection through the application of smoke screens or short-term fine-spray irrigation. The complex of tending operations includes weed control and soil loosening, which are performed simultaneously. Effective weed management is achieved through a combination of mechanical and chemical methods. To prevent soil crust formation and preserve moisture in the upper soil layer after rainfall or irrigation, post-emergence loosening with light harrows is conducted.

Norway maple seedlings typically reach standard parameters (stem diameter not less than 3 mm and height not less than 15 cm) within one year, making them suitable for outplanting in forest stands during the following growing season.

**Research Objective.** The objective of this study is to determine optimal sowing periods and evaluate the effectiveness of growth regulator application for intensifying growth and improving the quality of planting material of Norway maple under the conditions of Krasnopillia Forestry.

**Object of Research.** The object of research is the process of formation of qualitative characteristics of Norway maple planting material depending on sowing dates and the application of growth regulators.

**Subject of Research.** The subject of the study includes: sowing periods (September, October, November); sowing depth (1 cm, 2 cm); growth regulator treatments (Biosyl and control); morphometric parameters (height, root collar diameter, root length); phytomass ratio; and field germination.

**Research Tasks.** To achieve the stated objective, the following tasks were formulated:

To determine the effect of different sowing periods (September, October, November) and sowing depths on field germination of Norway maple seeds.

To study morphometric parameters (height, root collar diameter, root length) of one-year-old seedlings depending on sowing periods and seed treatment with growth regulators.

To determine the ratio of aboveground to belowground phytomass of seedlings to assess their adaptability and environmental resilience.

**Research Methods.** A comprehensive system of complementary methods was applied to ensure an objective assessment of the effects of sowing time optimization and growth regulator application on planting material quality. The visual method was used for systematic observations of phenological growth and development stages. The measurement-weight method was applied to determine key morphometric parameters, including seedling height, root collar diameter, main root length, as well as aboveground and belowground biomass for calculating their ratio. Mathematical and statistical analysis was conducted using analysis of variance (ANOVA) to determine the significance of differences between experimental treatments and to evaluate the contribution of each studied factor (sowing period, growth regulator, and their interaction).

**Research Results.** Despite the fact that Norway maple is not classified as a principal forest-forming species in the Forest-Steppe zone of Ukraine, it plays a significant role in shaping biodiversity, enhancing the resilience of forest ecosystems, and improving the qualitative characteristics of timber from dominant tree species. As an accompanying species, Norway maple is a valuable melliferous plant, contributes to the improvement of soil conditions through the rapid decomposition of leaf litter, and provides additional protection against soil erosion.

Contemporary challenges associated with climate change and increasing anthropogenic pressure necessitate the production of planting material with enhanced viability and adaptive potential. The quality of planting stock – particularly its morphometric parameters (height, root collar diameter, and root system development) – directly correlates with plant survival after outplanting and subsequent growth performance during the initial years. Therefore, optimization of cultivation technologies aimed at intensifying early growth stages is a critical task for ensuring successful afforestation and forest regeneration in the region.

One of the most effective silvicultural practices for significantly increasing seedling growth vigor and quality is the application of biologically active substances in combination with optimized sowing dates. The use of plant growth regulators stimulates physiological processes in germinating seeds, promoting enhanced cell division, improved root system formation, and accumulation of photosynthetic pigments. Investigating the efficacy of various formulations designed to intensify metabolism and increase resistance to stress factors is of particular relevance. Depending on their chemical nature and mechanism of action, growth regulators may exert differential effects on individual morphological parameters of maple seedlings, necessitating careful classification and analysis to identify the most effective treatments.

Sowing time is a key factor determining seed stratification conditions, the duration of the growing season, and consequently the quality of seedlings at the end of the growing period. Untimely sowing may result in uneven germination, reduced field emergence, or premature termination of vegetation, negatively affecting seedling height and diameter. The importance of this factor is further amplified under the conditions of the Forest-Steppe zone, where temperature regimes and soil moisture in spring and autumn are highly variable.

Seed germination capacity is one of the fundamental indicators of sowing quality and determines the potential stand density of future plantations. In forestry practice, two principal parameters are distinguished: laboratory germination and soil (field) germination. Although laboratory germination is a standardized indicator reflecting the biological viability of seeds under optimal controlled conditions (stable temperature and moisture, absence of pathogens), it does not fully represent germination success under natural nursery conditions.

Soil, or field, germination is a considerably more informative and practically significant indicator, as it reflects the ability of seeds to germinate and produce viable seedlings under conditions closely approximating real-world environments. Unlike laboratory testing, where adverse factors are eliminated, field conditions involve the combined influence of limiting factors such as heterogeneous soil temperature regimes, fluctuations in water balance, the presence of soil-borne pathogens, and competition from weeds.

The discrepancy between laboratory and field germination – often referred to as “field emergence” – is a critical consideration in planning silvicultural operations. As a rule, field germination is consistently lower than laboratory values, and this difference reflects both the sensitivity of seeds to external stressors and the extent to which sowing technology (depth, timing, soil preparation) aligns with the biological requirements of a given tree species. Identifying and minimizing this discrepancy, particularly through optimization of sowing dates and the application of growth regulators, constitutes an important research direction for producing high-quality and competitive planting material such as Norway maple. Thus, field germination serves as an objective criterion for both economic evaluation and technological improvement of seedling production processes.

The conducted studies made it possible to determine the specific patterns of field germination formation in Norway maple seeds depending on sowing date and sowing depth. Analysis of the data obtained for 2025 (Fig. 1) indicates that both factors had a significant effect on germination rates. Overall, the highest germination was recorded for October sowing, averaging 49.1 % (depending on depth), whereas September and November sowing resulted in germination rates of 40.8 % and 32.8 %, respectively. These findings confirm that autumn sowing periods are more optimal, as they ensure natural seed stratification under soil conditions during the autumn–winter period, which is essential for breaking seed dormancy in maple.

October sowing provided the maximum field germination. The highest value observed in the experiment – 52.9 % – was obtained at a sowing depth of 1 cm. This can be explained by the optimal combination of soil temperature and moisture, which creates favorable conditions for the initial stages of stratification while minimizing the risk of seed desiccation. Under the same sowing period, increasing the depth to 2 cm resulted in a 7.6 % decrease in germination (an absolute decline from 52.9 % to 45.3 %), likely due to reduced aeration and increased energy expenditure of the germinating seedling required to penetrate a thicker soil layer.

In the case of September sowing, which is relatively early for the autumn period, the average germination was lower compared to October. At a depth of 1 cm, germination reached 43.9 %, whereas increasing the depth to 2 cm reduced it to 37.7 %. The decrease of 6.2 % in this treatment was less pronounced than in October. This suggests that excessively early sowing may not fully utilize the benefits of natural stratification due to relatively high temperatures during the initial period; however, a clear trend of reduced germination with increased sowing depth remains evident.

The lowest field germination rates were recorded for November sowing, likely due to the onset of stable low temperatures and subsequent soil freezing shortly after sowing, which interrupts or complicates the initial phases of stratification and may cause mechanical damage to seeds. Notably, the difference between sowing depths of 1 cm (29.3 %) and 2 cm (36.3 %) was atypical: deeper sowing resulted in a 7.0 % increase in germination compared to shallow sowing. This unusual result may be attributed to improved thermal protection of seeds at greater depth during November, reducing exposure to temperature fluctuations and preventing desiccation at the soil surface under pre-winter conditions, thereby enhancing seed viability relative to less protected treatments. Nevertheless, even the highest germination observed in November (36.3 %) was significantly lower than the lowest value recorded for October sowing (45.3 %).

In general, the results substantiate the feasibility of selecting October as the optimal sowing period for Norway maple seeds at a sowing depth of 1 cm, as this treatment ensured the highest field germination (52.9 %), exceeding the best September treatment by 9.0 % and the best November treatment by 16.6 %. This confirms the high sensitivity of maple seedlings to silvicultural practices and underscores the importance of optimizing agrotechnical parameters

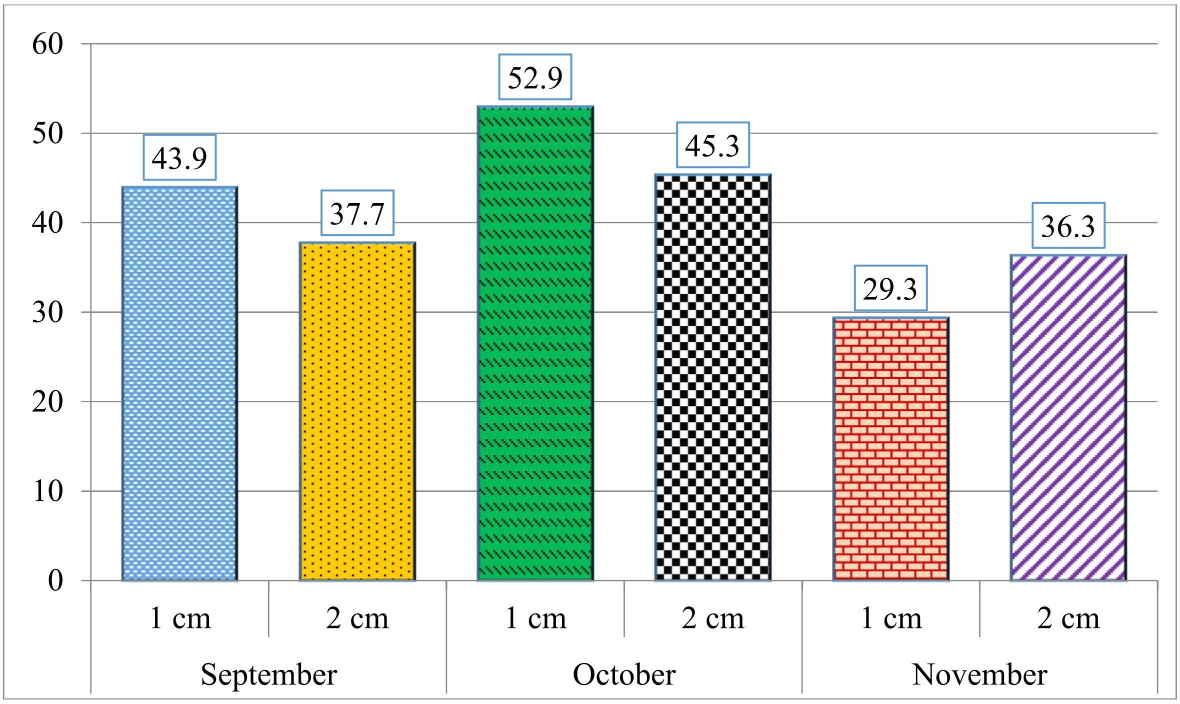


***Figure 1. Field germination of Norway maple seeds depending on the sowing date and depth in 2025, %***

The assessment of morphometric parameters of one-year-old seedlings constitutes an integral component in the development and improvement of intensive technologies for producing planting material in afforestation. Among all indicators, shoot height and root collar diameter are the most critical criteria for determining seedling standardization and predicting survival after outplanting to a permanent site. It is widely recognized that planting stock meeting established standards for these two parameters exhibits significantly higher viability and more intensive growth rates during the initial years of stand development.

Seedling height directly reflects the vigor of linear growth and the overall assimilative capacity during the growing season. This parameter serves as a direct indicator of the effectiveness of applied silvicultural practices, such as optimization of sowing dates and the use of biologically active substances. The greater the seedling height at the end of the growing season, the more rapidly it can overtop competing herbaceous vegetation and the lower the risk of damage by wildlife. Therefore, analyzing the effects of sowing dates (September, October, and November) and the growth regulator Biosyl on seedling height allows identification of the combinations that most effectively realize the growth potential of Norway maple.

The analysis of one-year-old seedling height in 2025 made it possible to determine the influence of factor A (growth regulators) and factor B (sowing date) on height formation (Table 1). Evaluation of mean values indicates a consistently positive effect of Biosyl application on linear growth compared to the untreated control. On average across all sowing dates, treatment with Biosyl resulted in a seedling height of 34.8 cm, whereas in the control variant this value was only 29.5 cm. This corresponds to an increase of 5.3 cm, or 18.0 %, attributable to the activation of growth processes, thereby confirming the effectiveness of biologically active substances in intensifying planting stock production.

With respect to factor B (sowing date), the highest mean seedling height, irrespective of treatment, was recorded for October sowing (35.1 cm). Slightly lower values were observed for September sowing (32.5 cm), while the lowest mean height (29.0 cm) was characteristic of seedlings sown in November. This trend confirms that October sowing is the most physiologically justified, as it ensures an optimal stratification period and maximum duration of vegetation for biomass accumulation, which is consistent with the previously established maximum seed germination for this sowing period.

A detailed analysis of factor interaction (AB) revealed that the tallest seedlings were obtained under October sowing combined with Biosyl application, where height reached 38.0 cm. This exceeds the corresponding untreated control (32.2 cm) by 5.8 cm. Such a substantial increase indicates a pronounced synergistic effect between optimal germination conditions provided by October sowing and the stimulatory action of the growth regulator.

It should be noted that even under the less favorable September sowing conditions, Biosyl treatment ensured a significant increase in growth: seedling height reached 35.2 cm, which is 5.5 cm higher than the control (29.7 cm). A similar trend was observed for November sowing, where the use of the growth regulator increased seedling height from 26.6 cm (control) to 31.3 cm (Biosyl), demonstrating the capacity of the preparation to partially mitigate the negative effects of late sowing and a shortened growing season.

Thus, the obtained results convincingly demonstrate that, for the production of high-quality Norway maple planting stock, the most effective approach is the combined application of the growth regulator Biosyl with October sowing, which enables the attainment of maximum height in one-year-old seedlings (38.0 cm).

**Table 1. Height of Norway maple seedlings as influenced by sowing date and application of growth regulators (2025), cm**

| Factor A (Growth regulator) | Factor B (Sowing date) | Seedling height, cm | Average for Factor B |
|---|---|---|---|
| Control (Untreated) | September | 29.7 | 32.5 |
| | October | 32.2 | 35.1 |
| | November | 26.6 | 29.0 |
| | **Average** | **29.5** | |
| Biosyl | September | 35.2 | |
| | October | 38.0 | |
| | November | 31.3 | |
| | **Average** | **34.8** | |

Root collar diameter, in turn, is an indicator reflecting seedling robustness and the reserve of nutrients (primarily starch and carbohydrates) accumulated in the lower stem and root system. A larger root collar diameter is directly correlated with the strength of mechanical tissues, resistance to lodging, and the ability of seedlings to withstand stress factors (drought, frost) during the critical period following transplantation. Therefore, research results identifying the optimal sowing date and growth regulator application that ensure maximum stem thickening are of decisive importance for developing technological recommendations aimed at producing first-class planting material. Consequently, a detailed quantitative analysis of these two interrelated morphometric parameters is essential for the scientific substantiation of the developed cultivation technology for Norway maple.

The results of studies on the formation of root collar diameter in one-year-old Norway maple seedlings in 2025 (Table 2), analyzed across two factors, demonstrated a pronounced positive effect of both growth regulator application and sowing date optimization on this morphometric trait. On average across all sowing dates, treatment with Biosyl resulted in a root collar diameter of 3.17 mm, which is 0.21 mm greater than in the control ("untreated"), where the mean value was 2.96 mm. The relative increase in diameter attributable to the regulator was 7.1 %, confirming its effectiveness in enhancing secondary growth processes and nutrient accumulation in the root collar zone.

With respect to factor B (sowing date), the highest mean root collar diameter, irrespective of growth regulator application, was observed under October sowing (3.13 mm). This result is fully consistent with the data obtained from the analysis of seedling height and indicates that October sowing provides the most favorable conditions for balanced growth and development of Norway maple seedlings. Slightly lower diameter values (3.03 mm) were recorded for both September and November sowing dates. Although identical in magnitude, these results indicate that both excessively early (September) and delayed (November) sowing limit the duration and intensity of growth processes, leading to a comparable reduction in stem thickening rates.

Analysis of factor interaction (AB) clearly demonstrated that the maximum root collar diameter (3.24 mm) was achieved under the combination of October sowing and Biosyl treatment. This finding indicates a synergistic effect of optimal environmental conditions (October sowing) and physiological stimulation (growth regulator application), which together create the most favorable conditions for intensive seedling thickening.

Moreover, even under September sowing conditions, the application of Biosyl ensured the formation of a diameter of 3.11 mm, which significantly exceeded the corresponding control (2.95 mm). It is also noteworthy that Biosyl application under November sowing resulted in a diameter of 3.15 mm, which is unexpectedly high, as it exceeded the diameter of seedlings treated with Biosyl but sown in September (3.11 mm).

**Table 2. Root collar diameter of Norway maple seedlings as influenced by sowing date and application of growth regulators (2025), mm.**

| Factor A (Growth regulator) | Factor B (Sowing date) | Root collar diameter, mm | Average for Factor B |
|---|---|---|---|
| Control (Untreated) | September | 2.95 | 3.03 |
| | October | 3.02 | 3.13 |
| | November | 2.91 | 3.03 |
| | **Average** | 2.96 | |
| Biosyl | September | 3.11 | |
| | October | 3.24 | |
| | November | 3.15 | |
| | **Average** | 3.17 | |

This result is likely attributable to the fact that the growth regulator effectively compensates for the shortened autumn growing season and promotes rapid seedling thickening in the spring, allowing for the accumulation of sufficient plastic substances to form a superior stem thickness compared to the September sowing variant. Despite this specific feature, the optimal combination remains the October sowing date in conjunction with Biosyl (3.24 mm).

The length of the main root exhibits a direct correlation with the drought resistance of the seedlings. Greater root length provides the plant with access to moisture and nutrients from deeper soil horizons, particularly under conditions of summer drought, which is indispensable for survival and intensive growth after transplanting [5, 18]. Since Norway maple is an associate species frequently utilized to enhance the stability of forest cultures, the formation of a developed and deep root system is a priority task. An analysis of the influence of sowing dates (September, October, November) and the application of the growth regulator Biosyl on this indicator allows for the identification of optimal agrotechnical solutions that stimulate geotropism and root growth energy.

The results of the study aimed at investigating the influence of Factor A (growth regulators) and Factor B (sowing date) on the formation of the main root length of one-year-old Norway maple seedlings in 2025 (Table 3) are of particular significance, as root system development is a determining factor for drought resistance and overall seedling resilience in permanent forest plantation areas. The analysis of mean values clearly demonstrates that the application of the regulator Biosyl had a pronounced growth-stimulating effect on the root system. On average across all sowing dates, treatment with this growth regulator allowed for the formation of a main root with a length of 24.4 cm, whereas in the control variants ("Untreated"), the average root length was only 18.7 cm. The difference amounts to 5.7 cm, or a 30.5 % advantage in favor of the Biosyl variant, confirming its high efficiency in activating the root's meristematic tissues.

When considering the influence of the sowing date (Factor B) on root length formation, an atypical but important trend is observed: the maximum average root length (23.2 cm) was recorded for the November sowing date, while the lowest indicators were observed for the September and October sowing dates – 20.8 cm and 20.6 cm, respectively. This result is likely explained by the fact that seeds sown in November undergo a more prolonged and intensive influence of low temperatures under conditions of natural stratification, which may promote more thorough post-harvest ripening and, consequently, more active root growth in the spring, while also forming a more resilient root system that enhances the quality of the planting material.

**Table 3. Main root length of Norway maple seedlings depending on sowing date and growth regulator application (2025), cm**

| Factor A (Growth regulator) | Factor B (Sowing date) | Main root length, cm | Average for Factor B |
|---|---|---|---|
| Control (Untreated) | September | 18.5 | 20.8 |
| | October | 17.0 | 20.6 |
| | November | 20.5 | 23.2 |
| | **Average** | **18.7** | |
| Biosyl | September | 23.1 | |
| | October | 24.2 | |
| | November | 25.9 | |
| | **Average** | **24.4** | |

A detailed analysis of the factor interaction (AB) allows for the identification of the optimal variant, which ensured the absolute maximum main root length of 25.9 cm. This indicator was obtained through the combination of the November sowing date and seed treatment with Biosyl. Compared to the control (untreated) in November (20.5 cm), the increment due to Biosyl was 5.4 cm. Simultaneously, Biosyl treatment during the October sowing date ensured a root length of 24.2 cm, which nearly corresponds to the maximum value and represents the most intensive increment compared to the October control (17.0 cm) – a difference of 7.2 cm, or an impressive 42.4 %. This indicates that while the October sowing in control variants forms the weakest root, the use of the regulator compensates for this deficiency to the greatest extent. Even for the September sowing date, Biosyl treatment increased the root length to 23.1 cm, compared to only 18.5 cm in the control. It was established that in all cases, the application of Biosyl increases root length; however, the November sowing date in combination with the growth regulator ensured the absolute maximum (25.9 cm), which is critical for ensuring the high quality of Norway maple planting material.

The ratio of aboveground to belowground phytomass is an integral indicator of seedling architectonics and one of the most objective criteria of its structural balance. In forest physiology and nursery practice, seedlings with lower values of this ratio (i.e., those possessing a relatively greater root mass compared to the shoot) are considered to be of higher quality and greater stability. Such a balance ensures improved physiological readiness to withstand transplant shock and increases the likelihood of successful establishment, as it minimizes the imbalance between a large transpiring surface (foliage) and an insufficient water-supplying system (roots) following lifting. Studies aimed at the targeted reduction of this ratio through the application of growth regulators demonstrate the possibility of managing physiological processes to obtain planting stock with enhanced ecological tolerance. Therefore, a detailed analysis of the effects of the studied factors on this parameter enables the development of a scientifically substantiated cultivation technology that ensures not only high-quality but also adaptive Norway maple planting material.

The results of studies on the aboveground-to-belowground phytomass ratio in one-year-old Norway maple seedlings for 2025 (Table 4) are of considerable ecological and practical importance, as this coefficient serves as an objective indicator of planting stock quality and adaptive potential. In afforestation practice, seedlings with lower values of this ratio are considered more resistant to adverse environmental conditions (particularly drought), as they possess a relatively better-developed root system.

Analysis of mean data clearly indicates that the application of the growth regulator Biosyl had a pronounced positive effect on this parameter by promoting its reduction. On average across all sowing dates, Biosyl treatment resulted in a ratio of 1.3, whereas in the untreated control this value was 1.8. The reduction of the ratio by 0.5 (or 27.8 %) confirms that Biosyl stimulated preferential root system development, which aligns with the requirements for high-quality planting material.

With respect to factor B (sowing date), the lowest mean ratio, irrespective of treatment, was recorded under November sowing (1.4), indicating the greatest relative advantage in root development for this variant. Higher values (1.6), reflecting a somewhat greater proportion of aboveground biomass, were characteristic of both September and October sowing. This pattern is consistent with root length data, where November sowing demonstrated a tendency toward enhanced belowground development, whereas September and October sowing – despite producing taller seedlings – resulted in a more balanced but less desirable biomass allocation.

A detailed analysis of factor interaction (AB) made it possible to identify the variant that ensured the most favorable (minimum) ratio of 1.1. This value was obtained under the combination of November sowing and Biosyl treatment. Compared with the untreated November control (1.7), the difference amounted to 0.6, or approximately 35.3 %, representing the greatest improvement among all experimental variants. This indicates a strong synergistic effect between physiological stimulation induced by Biosyl and the biological processes associated with late autumn sowing, resulting in planting material with an optimal root–shoot balance.

Even under October sowing conditions, Biosyl treatment ensured a low ratio of 1.3, which is substantially better than the corresponding control (1.9). Similarly, under September sowing, the ratio was 1.4 with Biosyl compared to 1.8 in the control. Across all treatments involving Biosyl, the ratio remained below 1.4, whereas in control variants it ranged between 1.7 and 1.9. This confirms that the application of Biosyl is the most effective silvicultural practice for deliberately shifting biomass allocation toward root system development in Norway maple seedlings.

**Table 4. Aboveground-to-belowground phytomass ratio in Norway maple seedlings as influenced by sowing date and application of growth regulators (2025).**

| Factor A (Growth regulator) | Factor B (Sowing date) | Shoot-to-root ratio | Average for Factor B |
|---|---|---|---|
| Control (Untreated) | September | 1.8 | 1.6 |
| | October | 1.9 | 1.6 |
| | November | 1.7 | 1.4 |
| | **Average** | **1.8** | |
| Biosyl | September | 1.4 | |
| | October | 1.3 | |
| | November | 1.1 | |
| | **Average** | **1.3** | |

The results of the analysis of variance (ANOVA), reflecting the influence share of the studied factors (growth regulator treatment and sowing dates) on the shoot-to-root ratio of one-year-old Norway maple seedlings, are essential for an objective assessment of the significance of each agrotechnical method and for identifying the primary regulators of this critical quality indicator. The shoot-to-root ratio serves as an integral quality criterion that determines the adaptive potential of seedlings, where a lower coefficient value indicates superior resilience to adverse environmental conditions.

It was established that Factor A (growth regulator) exerts the determining influence on the formation of the shoot-to-root ratio. Its share in the total variability of the indicator reached 86 %. This confirms that bioactive substances, specifically the regulator Biosyl, act as the primary tool capable of purposefully altering seedling architectonics by redistributing growth energy in favor of the root system (as previously demonstrated by the reduction of the coefficient to 1.1), which is of paramount importance for producing high-quality planting material. This result underscores the high efficiency of chemical stimulation over temporal (seasonal) parameters.

Factor B (Sowing date), although possessing a significantly smaller influence share, remains statistically significant, accounting for 11 % of the total variation. This influence is attributed to the varying duration of natural stratification and the growing season conditions provided by sowing in September, October, and November. Despite the dominant role of the growth regulator, the optimization of sowing dates remains important for the fine-tuning of biological processes and the formation of the desired ratio.

It is also noteworthy that the Interaction AB (Biosyl × Sowing date) demonstrates the smallest yet still significant influence share, amounting to 3 %. This indicator suggests that while synergistic effects exist (as shown by the November sowing + Biosyl yielding the optimal result of 1.1), they are not the primary source of variation. The core variability of the indicator, totaling 86 %, is unequivocally linked to the action of the Biosyl preparation itself, rendering it the priority agrotechnical measure in the cultivation technology of Norway maple.

Thus, the results of the analysis of variance scientifically substantiate that the primary factor determining the balanced development of Norway maple seedlings and their potential resilience is the application of a growth regulator, which should form the basis of recommendations for the intensification of planting material cultivation.

**Conclusions.** Established that the October sowing date is optimal for achieving high field germination of Norway maple seeds. The maximum germination rate of 52.9 % was recorded for October sowing at a depth of 1 cm. This value is 9.0 % higher compared to the best September sowing variant and 16.6 % higher than the best November variant, confirming the significance of sowing depth and timing for natural stratification.

Revealed a positive effect of treating seedlings with the growth regulator Biosyl on the morphometric indicators of one-year-old Norway maple seedlings. On average across all sowing dates, the application of Biosyl ensured an increase in seedling height by 18.0 % (to 34.8 cm versus 29.5 cm in the control) and an increase in root collar diameter by 7.1 % (to 3.17 mm versus 2.96 mm in the control).

Determined a synergistic effect of factor interaction that ensured the formation of the tallest seedlings. Maximum height (38.0 cm) and root collar diameter (3.24 mm) were achieved with the October sowing date combined with the application of the growth regulator Biosyl, indicating this variant as the most effective for achieving standard parameters of the above-ground part.

Ascertained that the maximum main root length of one-year-old seedlings (25.9 cm) was ensured by the combination of the November sowing date and seedling treatment with Biosyl. In this variant, the increment due to the regulator was 5.4 cm compared to the control. However, the highest relative increment in root length (42.4 %, or 7.2 cm) was recorded for the October sowing date following Biosyl treatment (24.2 cm versus 17.0 cm in the control).

Established that the application of Biosyl leads to a shift in the biomass balance in favor of the root system, which is a desirable trait for increasing the adaptability of planting material. The most favorable minimum shoot-to-root ratio of 1.1 was obtained with the November sowing date combined with Biosyl treatment. This is 35.3 % lower compared to the corresponding control (1.7), confirming that Biosyl effectively stimulates the preferential development of the underground part, which is critical for drought resistance.

Proven that the application of the growth regulator Biosyl is the primary factor determining seedling balance. This factor accounts for 86 % of the influence on the variability of the shoot-to-root ratio. Due to the action of Biosyl, the most desirable coefficient (1.1) was obtained during the November sowing date, which is 35.3 % lower than the control and indicates a purposeful shift of the biomass balance in favor of the root system.

Recommended that to ensure the maximum yield of standard Norway maple planting material characterized by an optimal balance of above-ground and underground parts, the integrated application of seedling treatment with the growth regulator Biosyl is most expedient. Furthermore, the October sowing date is optimal for maximizing height and diameter, while the November sowing date is optimal for ensuring maximum root system development and a superior biomass ratio.

**Recommendations.** Under the conditions of the Krasnopillia forestry enterprise, to increase the field germination rate and obtain high-quality Norway maple planting material, it is recommended:

- To perform seed sowing in October at a depth of 1 cm;
- To form planting material with the most developed root system, it is advisable to treat seedlings with the growth regulator "Biosyl" during the spring period at a dosage of 20 ml/ha with a working solution consumption of 300 l/ha.

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