SPATIAL RELATIONSHIPS AND MANAGEMENT SYSTEMS IN FOREST, PARK, AND AGRICULTURAL COMPLEXES IN THE CONTEXT OF MODERN CHALLENGES AND SUSTAINABLE DEVELOPMENT

Edited by

Melnyk Tetyana

RS Global
Monographs

Warsaw, 2025

SPATIAL RELATIONSHIPS AND MANAGEMENT SYSTEMS IN FOREST, PARK, AND AGRICULTURAL COMPLEXES IN THE CONTEXT OF MODERN CHALLENGES AND SUSTAINABLE DEVELOPMENT

Monograph

According to the Scientific Edition
Candidate of Biological Sciences
Professor
Melnyk T.I.

RS Global
Warsaw, Poland
2025

DOI: 10.31435/rsglobal/061

Recommended for publication by the Academic Council of Sumy National Agrarian University (№ 17 from 31.03. 2025).

Reviewers:
Mykola Sakhoshko
Candidate of Agricultural Sciences, Director of the Sumy Branch of the Ukrainian Institute of Plant Variety Examination;
Volodymyr Trotsenko
Doctor of Agricultural Sciences, Professor, Head of the Agrotechnology and Soil Science Department, Sumy National Agrarian University;
Serhii Kovalevskii
Doctor of Agricultural Sciences, Professor of the Botany, Dendrology and Forest Breeding Department, National University of Life and Enviromental sciences of Ukraine.

Authors: Melnyk Andriy, Melnyk Tetyana, Horbas Serhii, Butenko Sergey, Stoyanets Nataliya, Tokman Volodymyr, Viunenko Oleksandr, Horbas Serhii, Kremenetska Yevheniia, Osmachko Olena, Tetiana Boiko and others.

Melnyk, T. I. (Ed.). (2025). *Spatial Relationships and Management Systems in Forest, Park, and Agricultural Complexes in The Context of Modern Challenges and Sustainable Development.* RS Global Sp. z O.O.

ISBN 978-83-970624-3-6 (eBook)

This monograph offers a comprehensive analysis of spatial relationships and management systems within forest, park, and agricultural complexes, addressing contemporary challenges and sustainable development imperatives. It is intended for researchers, educators, graduate students, policy makers, business leaders, and all those engaged in the fields of agriculture, forestry, and horticulture. The volume encompasses a diverse array of topics, including techniques for preserving the marketable freshness of plant materials, methods of propagating medicinal and ornamental species, and strategies for maintaining the ecological sustainability of forest and park environments. Particular emphasis is placed on regional studies concerning Quercus robur and Quercus rubra, as well as on the application of artificial intelligence in the digital design of garden and park spaces. Additionally, the monograph explores progressive practices in environmental assessment and land management across Ukrainian communities. The interdisciplinary contributions compiled herein provide both theoretical frameworks and practical solutions aligned with the principles of sustainability and environmental stewardship.

ISBN 978-83-970624-3-6 (eBook)

TABLE OF CONTENTS

Introduction……………………………………………………………………………… 4
Melnyk Tetyana, Melnyk Andrii, Trotska Svitlana
FEATURES OF PRIMARY PROCESSING OF CUT PLANT MATERIALS IN ORDER TO PRESERVE MARKETABLE FRESHNESS……………………………….. 5
Melnyk Andrii, Dudka Anhelina, Sonora Yevhenii, Oleksandr Chemerys
CONDITION AND METHODS OF REPRODUCTION OF THE *QUERCUS ROBUR* L. POPULATION IN THE CONDITIONS OF THE LEFT-BANK FOREST-STEP OF UKRAINE………………………………………………. 16
Horbas Serhii, Kytaihora Anton, Koval Serhiy
PECULIARITIES OF GROWING *QUERCUS RUBRA* L. IN THE CONDITIONS OF SUMY REGION………………………………………………………… 49
Horbas Serhii, Kytaihora Anton, Prokofiev Dmytro
MEDICINAL PLANTS: PROPERTIES, APPLICATIONS, AND PROSPECTS…………... 63
Osmachko Olena, Horbas Serhii
THE ROLE HUDRANGEA (HYDRANGEA L.) IN ORNAMENTAL GARDENING AND FLORISTRY: PROPAGATION CHARACTERISTICS……………... 83
Tokman Volodymyr
TECHNOLOGICAL ASPECTS OF GROWING SALVIA POPULUS × CANADENSIS FOR THE CREATION OF FOREST PLANTATIONS IN THE NORTHEASTERN FOREST-STEPPE OF UKRAINE…………………………… 102
Tokman Volodymyr
ROOTING ABILITY OF STEM MICROPROPAGULES OF FICUS BENJAMINA L. AND THE POSSIBILITY OF THEIR FURTHER USE IN INTERIOR LANDSCAPING……………………………………………………………... 110
Tokman Volodymyr
INFLUENCE OF FACTORS ON THE EFFECTIVENESS OF VEGETATIVE PROPAGATION OF SOME SPECIES OF ORNAMENTAL PLANTS…... 119
Serhii Butenko
CONDITIONS FOR THE CREATION OF FOREST CULTURES IN THE TERRITORY OF THE NORTHEASTERN FOREST-STEP OF UKRAINE……………….. 126
Viunenko Oleksandr
CURRENT TRENDS IN THE USE OF ARTIFICIAL INTELLIGENCE (AI) FOR COMPUTER-BASED DESIGN OF GARDEN AND PARK OBJECTS……………… 143
Andreieva Olena, Shvets Maryna, Martynchuk Ivan, Marchuk Danylo
MONITORING OF TREES DETERIORATION FACTORS IN THE URBAN CENOSES OF ZHYTOMYR CITY……………………………………………………. 168
Tetiana Boiko,Pavlo Boiko
COMPOSITION SOLUTIONS FOR THE CREATING FLOWER ARRANGEMENTS IN THE KROPYVNYTSKY CITY…………………………………… 191
Nataliya Stoyanets
FOREIGN EXPERIENCE IN PLANNING HORTICULTURAL AND PARK MANAGEMENT TAKING INTO ACCOUNT INNOVATIVE ACTIVITIES……... 212
Yaroshchuk Svitlana,Yaroshchuk Roman
GREEN SPACES IN THE FOCUS OF STRATEGIC ENVIRONMENTAL ASSESSMENT: CHALLENGES AND PRACTICES OF UKRAINIAN COMMUNITIES…………………………………………... 225

INTRODUCTION

Spatial organization and management of forest, park and agricultural complexes are key aspects of sustainable development and efficient use of natural resources. These systems play an important role in ensuring ecological balance, preserving biodiversity, producing food and creating recreational opportunities. However, modern challenges, such as climate change, population growth, urbanization and agricultural intensification, create significant pressure on these systems, requiring innovative approaches to their management. In the context of modern challenges, understanding spatial relationships and developing effective management systems in forest, park and agricultural complexes is becoming particularly relevant. The need to adapt to climate change, mitigate its consequences, ensure food security and preserve natural ecosystems requires a comprehensive and integrated approach to land resources management. Effective management of spatial organization allows to optimize the use of land plots, increase agricultural productivity, improve the quality of forest resources and provide a comfortable environment for rest and recreation. In addition, reasonable management of these complexes contributes to the preservation of biodiversity, protection of soils and water resources, as well as reducing the negative impact on the environment. The study of spatial relationships and the development of modern management systems in forest, park and agricultural complexes is an important step towards sustainable development, ensuring a balance between the economic, social and environmental needs of society.

The materials presented within this monograph are unified by a common objective: to contribute to the establishment of an effective mechanism for supporting agrarian transformations in Ukraine. The research encompasses key sectors, namely agriculture, forestry, and park and garden management. The authors' work reflects their endeavor to adapt the obtained findings to contemporary realities, while considering international standards in labor relations and management practices prevalent in developed countries. From this perspective, the research presented in this monograph is both novel and of significant value.

The authors acknowledge that the conclusions and judgments put forth are not exhaustive. The rapid changes occurring within Ukraine's agrarian sector, specifically in agriculture, forestry, and park and garden management, continuously necessitate revisions to both theoretical frameworks and practical approaches to sustainable rural development management. The monograph is characterized by a successful integration of clarity of exposition and scientific rigor. Within its scope, specific proposals and approaches are presented to address pertinent issues related to the improvement of agrarian transformation in Ukraine, particularly within the agricultural, forestry, and park and garden management sectors.

We express our sincere gratitude to the reviewers of this publication Mykola SAKHOSHKO, candidate of Agricultural Sciences, Director of the Sumy Branch of the Ukrainian Institute of Plant Variety Examination; Volodymyr TROTSENKO, doctor of Agricultural Sciences, Professor, Head of the Agrotechnology and Soil Science Department, Sumy National Agrarian University; Serhii KOVALEVSKII, doctor of Agricultural Sciences, Professor of the Botany, Dendrology and Forest Breeding Department, National University of Life and Enviromental sciences of Ukraine.

FEATURES OF PRIMARY PROCESSING OF CUT PLANT MATERIALS IN ORDER TO PRESERVE MARKETABLE FRESHNESS

Melnyk Tetyana
Candidate of Biological Sciences, Professor, Sumy National Agrarian University, Ukraine
ORCID ID: 0000-0002-3839-6018

Melnyk Andrii
Doctor of Agricultural Sciences, Professor, Sumy National Agrarian University, Ukraine
ORCID ID: 0000-0001-7318-6262

Trotska Svitlana
PhD, Sumy National Agrarian University, Ukraine
ORCID ID: 0000-0003-2089-5780

Introduction. Cut flowers are a special type of product for which traditional methods of preservation inherent in agricultural practice are not always suitable. Unlike crop agricultural products, flowers do not have a dormant period, which makes their long-term storage much more difficult. The introduction of modern technologies and methods of preserving cut flowers in industrial floriculture allows to increase production efficiency, minimize losses and provide consumers with flower products.

The influence of light and temperature on the induction of flowering, the transition from vegetative to floral state, flowering in vitro, flower genetics, as well as issues related to pre-harvest conditions were studied in the works of Teixeira da Silva, J.A. and D.T. Nhut D.T.

Williams M.FI. et al. studied the physiology of aging of cut flowers. Flowers are called climacteric or non-climacteric depending on when the ethylene and respiratory peak occurs during petal wilting. In climacteric species, ethylene production, which is induced in response to ethylene, plays a central role in petal senescence, suggesting its involvement in both the initiation and regulation of senescence, while the activity of ACC synthase and ACC oxidase increases dramatically before senescence begins, which does not occur in nonclimacteric species

Van Doom, W.G. and P. Cruz in their research drew attention to the fact that in the petals of cut flowers that undergo aging, the protein content decreases, the activity of proteases increases, the fluidity of lipids in the membranes decreases and the respiration rate increases. It was found that petal aging is accompanied by morphological, biochemical and biophysical deterioration. In aging carnation flowers, a climacteric increase in ethylene production is observed, and exposure of carnation flowers to exogenous ethylene induces petal curling, triggers ethylene synthesis, and induces chemical and physical changes in the lipids of microsomal membranes of aging petals.

Williams et al. (1995) found that in chrysanthemum, which is not a climatic plant, ethylene does not play a role in flower senescence, with only minor changes in protein content and the ratio of major polypeptides (Williams et al., 1995), which explains the long life of chrysanthemum after harvest. Conditions that inhibit the action of, for example, silver salts, sodium benzoate or boric acid, or ethylene synthesis, for example, by supplying a-amino-oxyacetic acid (AOA), extend the life of carnations in the vase; an invertase inhibitor, which is apparently synthesized in the wilting petals of a number of flowers (morning glory, alstroemeria, carnation, dahlia, gladiolus, petunia, and rose), affects petal aging by blocking the hydrolysis of sucrose to glucose and fructose in aging tissues, which may control the translocation of sucrose from wilting petals to other organs of the flower [.

Rose petal shedding is not affected by water status, as long as the plants do not reach a low water potential at the beginning of their vase life, and are not inhibited by low light intensity and are not dependent on the Pr/Pfr ratio.

Among the Ukrainian studies, Sorokina S.V., Akmen V.O., Letun T.I. devoted their works to the study of storage conditions for preserving the decorative effect of cut roses, noting that the most effective method of storing cut roses is the use of a regulated gas environment in combination with the recommended wet cold storage. Such storage allows to reduce losses by 2-3 times.

An important aspect of the floristic business is a careful attitude to environmental protection. The issue of studying the environmental safety of packaging materials, floral foam, aerosol sprays to make plants look more attractive during sale is devoted to the works of Dontsova V.V., Lebedenets V.T. and Sapozhnyk D.I., Butko M.P. and Solomakha I.V.

Ahmad Iftikhar, Dole J.M., Clarke E.M.R. and Blazic F.A. (2014). investigated the effect of floral foam (Oasis®) with conventional and organic preservatives to determine the optimal treatment for extending the life of cut roses (Rosa × hybrida L.) cultivars 'Freedom' and 'Charlotte'. Overall, floral foam resulted in similar or reduced lifespan in cut roses 'Freedom' and 'Charlotte' placed in pots and had no effect on aging symptoms in either cultivar. 'Freedom' showed more browning of petals and rot, as well as reduced bud opening compared to 'Charlotte'. Vase solutions containing one of the two conventional preservatives resulted in longer vase life for both cultivars than stems in deionized (DI) water. Flower foam saturated with DI water resulted in greater changes in vase solution pH in both varieties. Among the preservatives tested, conventional products such as Floralife Premium Rose Food or Chrysal Rose Vase (each 10 ml/L) extended the life of the arrangement by 5.5 or 3.9 days, respectively; while organic products such as Vita Flora or Vita One Step (each 0.53 ml/L) resulted in statistically similar vase life (9.3 days or 8.3 days, respectively) as stems in DI water (7.5 days), regardless of the use of floral foam. These results indicate that floral foam should not be used when treating cut rose stems after harvest. In addition, conventional preservatives were more effective than organic preservatives.

The current Ukrainian flower market is capable of providing consumers with almost 80% of its own production**.** Ukrainian flower growers are able to produce up to 100 million roses. An important obstacle to filling the domestic market and reaching export capacities is overcoming the barrier of storage time by optimizing storage conditions.

The study of storage conditions for preserving the decorativeness of cut roses is devoted to the work of Sorokina S.V., Akmen V.O., Letun T.I., who noted that the most effective method of storing cut roses is the use of a regulated gas environment in combination with the recommended storage in a wet cold way. Such storage allows to reduce losses by 2-3 times.

The use of optimal flower handling procedures (increased sanitation and innovative preservation using inexpensive and environmentally friendly products) will result in better appearance and longer life of cut flowers, foliage and plants in vases and arrangements. Long-lasting quality flowers mean less wastage in the processing cycle. Ultimately, this means more enjoyment and more satisfaction for the consumer. Understanding the biophysical and genetic mechanisms that control the physiological processes in both flower parts and leaves will allow for the development of new, transgenic varieties with longer cut flower life and better post-harvest characteristics (persistent color, aroma, shape).

The study of ways to extend the life and preserve the decorative properties of cut flowers is inextricably linked to understanding the mechanisms of their aging and wilting. After cutting, the flower-bearing shoot finds itself in conditions that lead to a violation of the water balance. Separated from the root system, the stem with leaves and a flower continues to actively evaporate moisture, especially at high temperatures, but cannot compensate for its loss. The cut site on the shoot is a damaged area that, together with air bubbles, clogs the conducting vessels, making it difficult for water to enter even after immersion in the liquid. An additional factor in the blockage of blood vessels is the active development of putrefactive microorganisms in the aqueous solution.

In addition, after cutting, sap is released from the plant's vessels, resulting in compounds harmful to the flower. Tap water contains calcium, magnesium, fluoride and other elements, the concentration of which can negatively affect cut flowers. All the basic life processes continue to take place in their tissues, but their direction differs from the processes in plants that remain with the root system. After cutting off, the flower shoot loses the ability to receive not only water and nutrients, but also important biological compounds such as hormones, vitamins, and enzymes. Their lack leads to metabolic disorders, the prevalence of decay processes, accelerated aging and wilting of flowers.

The first mentions of using chemicals to extend the life and preserve the quality of cut flowers appeared in the early 20th century in Western Europe and the United States. At that time, flower growers, both scientists and practitioners, were actively researching the effect of various chemical compounds on the duration of preservation of decorative properties of plants. They tested a wide range of substances in an effort to find an effective means to reduce the wilting rate and extend the life of cut flowers.

Among the compounds used, solutions of boric and nitric acids, potassium permanganate and nitrate, sucrose, and aspirin yielded positive results. Their use to increase the freshness of such flower crops as carnation, chrysanthemum, poppy, aster, phlox, and others was particularly notable. However, despite certain successes, all these methods were found to be ineffective for mass use.

In the 1930s, a special nutrient solution for cut flowers was developed in the Netherlands, the main component of which was glucose with the addition of a small amount of mineral salts. It was assumed that this composition would help compensate for the lack of nutrients and prolong the freshness of the plants. However, like many other methods, this solution was not widely used in practice. The main reasons for this were insufficient scientific substantiation of the research, as well as the fact that the tests were mainly on open-pollinated crops, which gradually lost their importance in modern industrial floriculture.

Thus, although the first attempts to use chemicals to extend the life of cut flowers yielded some results, they did not lead to the creation of a universal effective method that could be widely used in industrial floriculture. This was the impetus for further research, which subsequently contributed to the development of more effective technologies and methods for preserving cut plants.

Relatively recently, after flower scientists discovered the main causes of wilting of cut flowers, they began to actively use chemicals and their mixtures to extend their freshness. The individual components of these compounds to a certain extent provide the functions of physiologically active substances, affecting the life processes of plants. Conventionally, these substances are divided into three main groups: substances that slow down metabolic processes - inhibitors and retardants; substances that stimulate metabolic processes and maintain plant viability - plant growth stimulants, physiologically active substances; substances that prevent the development of putrefactive microorganisms - antibiotics, antiseptics, preservatives, etc.

The first group necessarily includes such compounds as maleic acid hydrazide (MHA), chlorocholine chloride, tour (CCC) and its salts, dimethyl succinic acid hydrazide (alar), abscisic and fusaric acids, coumarin, thiouracil, etc. They inhibit the activity of metabolic processes, which allows to extend the freshness of the cut flower.

The second group includes growth stimulants known as cytokinins. One of the most effective representatives of this group is kinetin. In addition, purine and pyrimidine compounds play an important role in maintaining the vitality of flowers, and then they become part of nucleic acids. The treatment of cut flowers with such substances slows down the aging of the tissue, prevents the breakdown of chlorophyll, proteins and organic acids, while activating the synthesis processes in plant cells.

Auxins, such as heteroauxin and gibberellin, are naturally occurring compounds that stimulate cell growth and elongation in plants. without them, other synthetic growth regulators, such as anaphthyllucic acid and 2,4-D derivatives, which do not occur naturally but in small concentrations can have a positive effect on the preservation of the decorative quality of cut flowers.

Organic acids, such as succinic, malic, and citric acids, as well as vitamins, such as ascorbic acid (vitamin C), in combination with other substances, support plant metabolism. Some polyphenols and quinolines are also physiologically active compounds. For example, quinoline derivatives, including 8-oxyquinoline citrate (QC) and 8-oxyquinolinecalcium phosphate (QQP), help regulate water metabolism, reduce vascular occlusion, and slow down the aging process. HC is also noted for its ability to inhibit the development of pathogenic microorganisms.

For the preservation of cut flowers, their ability to absorb nutrient solutions is of great importance, which is significantly increased by the introduction of potassium, sodium, boron, aluminum, etc. into the solution. However, the main energy or nutrient materials for cut flowers are various sugars (sucrose, glucose, fructose, etc.). Many scientists point out that sugars− are a source of energy for maintaining plant life at a certain level - they have a positive effect on the stability of cut flowers, stimulate respiration, reduce evaporation and ethylene emission.

One of the ways to prolong the freshness of cut flowers is to use antimicrobial substances in nutrient solutions, which make up the third group. Studies confirm the effectiveness of compounds such as silver nitrate, salicylic and boric acids, thymol, resorcinol, and potassium permanganate,

To preserve the decorative effect of cut flowers, it is necessary to use all these groups of compounds in combination, observing the optimal combinations and concentrations depending on the type of plant and other factors.

Today, the flower market offers a variety of nutrient mixtures for lengthening cut flowers. The composition and formulation of nutrient mixtures may vary, but the principle of their creation has much in common. Such mixtures must contain carbohydrates (sugars), growth regulators, disinfectants, and substances that promote the transport of nutrients to plants and reduce water hardness.

The concentration of sugars can vary from 1 to 6% (10-60 g/l). Flowers cut in the dense bud phase require more sugars to continue their developmental processes. While for fully opened buds, the concentration can be reduced, after which their growth is completed and metabolic processes slow down.

The formulations of many effective foreign products for preserving cut flowers, such as Chrysal (Netherlands), Flower Food (Canada), Fresh Flower (Germany), Smithers Oasis, Floralife® (USA) and others, are patented and not disclosed. At the same time, various nutrient solutions are used in Ukraine, developed by scientific and research institutions, including Buton, Buton-2, Vitant, Nora, Bouquet. They are suitable for a wide range of cut flowers and have available, safe, and inexpensive ingredients. Studies have shown that Buton and Buton-2 are particularly effective for preserving carnations and roses.

Many domestic and foreign products have a complex formulation, contain expensive and hard-to-find components, and sometimes even toxic substances that can color solutions in undesirable shades or give them an unpleasant odor.

Materials and methods of research. The purpose of the study was to investigate the effect of drugs on the life expectancy of rose and chrysanthemum cuttings using floral foam. The two most popular species were chosen as the material for the study - rose bush and Indian chrysanthemum, which are characterized by multi-flowered shoots.

Indian chrysanthemum (spray) Kennedy White is a variety with small flowers of pale pink color. The flowers have a diameter of 4-5 cm. From 3 to 7 buds are formed on one branch. Shoots up to 70 cm high are sold in florist shops. It is considered one of the most resistant to wilting.

Shrub rose (spray) Snow World® is a peony-like variety characterized by particularly lush flowering. The flowers appear in clusters of 5-20 pieces. The flowers are 5-7 cm in diameter, the petals are delicate, collected in dense buds. The variety is odorless and almost does not form thorns. Cut flowers retain their freshness for a long time, so they are often used to create bouquet compositions.

The research was carried out on cut chrysanthemum and rose stems formed in the form of a stationary floral arrangement based on floral foam. These species and varieties were selected based on the results of a survey of florist shop sellers as the most popular among consumers. To extend the shelf life of cut flowers, we used the most popular preservatives among florists: "Flora Active (dextrose, ammonium sulfate and citric acid), Floral Preservative (carbohydrates, vegetable organic acids, trace elements, phytohormones, water), Chrysal Flower Boost (composition is classified by the manufacturer), Forte (sucrose hydrochloride, alum, boric acid, perfume). The samples were purchased from a flower shop that received the flowers fresh and stored in a professional floristic refrigerator at 4-5 °C for one day. By agreement, the seller did not perform any additional processing of the samples.

The technique of primary processing of flowers, which we carried out at the beginning of the experiment, consisted of renewing the cut with a florist's knife, removing excess leaves from the stem to a height of 15 cm. After purchase, the cut flowers were placed in clean glass vessels with a solution of the preparations. The water used was ordinary tap water to simulate the buyer's home conditions. The water temperature for the experiment was within the recommended range (+12-15 ^{o}C). A pure tap water solution was chosen as a control.

The preparations were dissolved in water in accordance with the recommendations of the manufacturers indicated on the packages: "Flora Active (5 ml per 1 liter of water), Floral Preservative (10 ml per 1 liter of water), Chrysal Flower Boost (5 g of the preparation per 500 ml of water), Forte (15 g per 1.5 liters of water). Floral foam briquettes were kept in the same solutions until they were completely wet. The changes were photographed at intervals of 1-3 days from the date of composition. Changes in the characteristics were recorded according to such parameters as petal color, petal shape, peduncle turgor, leaf turgor, and overall decorativeness was assessed. The results of the study of the preservation of flower decorativeness were based on a scoring system (Table 1).

Results. Floral industry workers and ordinary buyers of floral arrangements are well acquainted with the green, moisture-absorbing blocks used to form floral arrangements − with floral foam. It first entered the flower market in the 50s of the 19th century in the United States of America. It is a by-product of Smithers-Oasis, which accidentally turned out to be useful for packaging and design by modern florists. Not only does it absorb and hold water up to 50 times its weight, but it can also support the stem of a flower or leaf in the right position and allow water to flow to the stem. As a packaging option, it makes it easier to transport flower arrangements by holding the stems in place and preventing water from spilling. These features of floral foam have allowed floral design to move in unusual directions as the arrangement process has become easier and faster, and has allowed for more complex designs. Prior to the invention of floral foam, florists made their arrangements directly in vases or pots of water, using wire or metal pins to secure the stems in the desired position.

By origin, floral foam is a type of foam whose structure is similar to that of a plant stem (Fig. 1), which, according to scientists, is the basis for successful water exchange between them.

Table 1. Scale of preservation of decorative qualities of cut flowers (after K. Lutfullina et al, 2023)

Sign.	**Evaluation points**
Color of the petal	5 - rich, intense, corresponds to the description of the variety; 4 - darkening along the edges of 10% of the petal area; 3 - darkening along the edges of 20% of the petal area; 2 - strong darkening along the edges of 50% of the petal area; 1 - darkening of more than 50% of the petal area
Petal shape	5 - the shape corresponds to the description of the variety; 4 - slight loss of turgor in some petals; 3 - change in shape of all petals, loss of turgor; 2 - twisting the petals to the center; 1 - compression of the petals to the center as much as possible
Turgor of the peduncle	5 - the basket is directed upwards; 3 - there is an inclination of the peduncle; 1 - the basket is directed downward
Condition of the stem	5 - the stem is green, elastic, filled with moisture 3 - darkening appears, begins to lose moisture 1 - drying of the stem, color change to a darker color, the beginning of decay
General decorative effect	5 - rich color of the petals without flaws, the peduncle is directed vertically upwards, the leaves are green, juicy; 4 - slight loss of turgor, darkening on some petals (25%), elastic leaves; 3 - the beginning of petal necrosis, loss of turgor, peduncle bending, leaves 50%; 2 - massive necrosis, severely twisted petals, severe loss of turgor - 75%; 1 - loss of color brightness, strong twisting of petals, peduncle is lowered down, leaves with dry ends twisted - 100%.

The most valuable feature of the marketability of cut flowers is the duration of the inflorescence's decorative effect. We have analyzed the shelf life and dynamics of changes in the state of inflorescences during storage in different solutions. The results of the observations are shown in Table 2.

It should be noted that under the studied storage conditions, both species showed the same inflorescence reactions. The manifestations of the stages of change in decorativeness occurred simultaneously in both the shrub rose and the Indian chrysanthemum. We have presented the average observation periods.

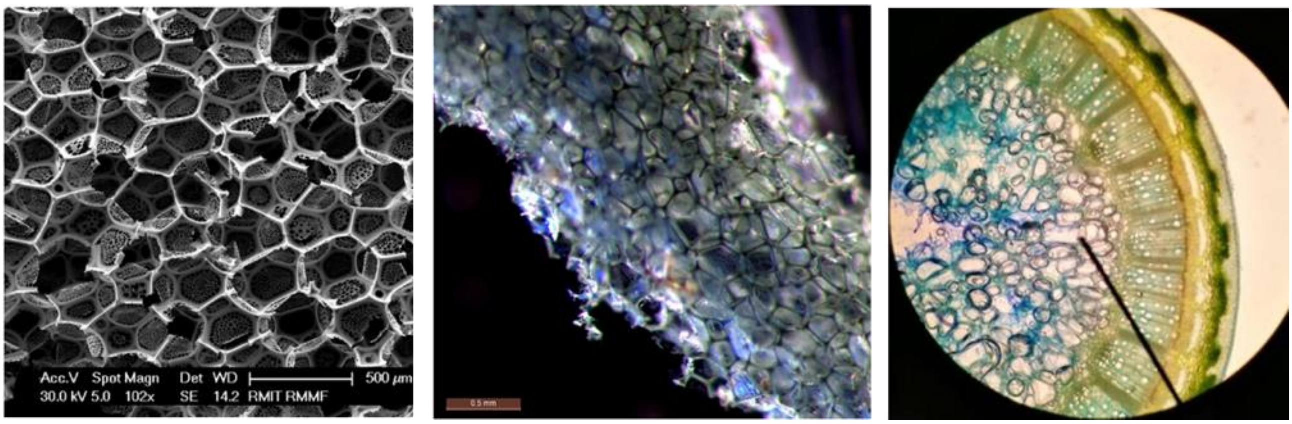

Fig. 1. *The structure of floral foam (1, 2 photos) and a section of a rose stem under a microscope*

The compositions were formed on April 19. They were stored at room temperature away from direct sunlight. The room humidity was standard. No additional treatments were used for the compositions.

Table 2. Average values of the life expectancy of inflorescences of the studied species in the composition on different solutions

Option.	Date of composition filing	Inflorescence stage				Duration. decorativeness, days
		lowering of the petals	curling of petals	loss of color, shape and turgor	darkening, drying out	
Control	19.04	21.04	23.04	27.04	29.04	11
Flora asset	19.04	25.04	29.04	03.05	06.05	17
Floral preservative	19.04	23.04	25.04	27.04	30.04	12
Chrysal Flower boost	19.04	27.04	02.05	06.05	10.05	26
Fleur Eau	19.04	25.04	29.04	02.05	04.05	17

The first signs of petal shape changes began to appear on the control on the third day of storage, when using Floral Preservative on the 5th day. Flora active and Fleur Eau slowed the onset of petal curling to 7 days, and Chrysal Flower boost - to 9 days.

A pronounced loss of decorativeness of inflorescences was observed in the control and soaking in "Floral Preservative", which was 9 days from the date of composition. The darkening and drying of more than 75% of the petal and inflorescence area in these variants was recorded on day 11-12. For the other preparations, the duration of decorativeness was determined to be 17 days for Flora active and Fleur Eau. The use of Chrysal Flower boost made it possible to use the compositions for up to 26 days with a slight loss of overall decorativeness (Fig. 2).

Fig. 2. *Dynamics of decrease in decorative effect of flower arrangements at different*

The results of the observations showed that the rose had an average score of 5 points in terms of color and petal shape in the first five days. Starting from the seventh day, signs of darkening of the petals began to appear, and on the 11th day, darkening of the petals became characteristic of compositions in all solutions, except for "Floral Preservative". The compositions treated with this preparation had a darkening of 50% of the petals, which was evaluated at 2 points.

On the 14th day of observations, the composition formed using "Floral Preservative" received a score of 1, because under its action, mold appeared on the stems and floral foam, which had a very pronounced unpleasant odor. All the other solutions received a total score of 3 points. By day 17, the flowers had completely lost their presentation. Chrysal Flower boost turned out to be the best preparation for preserving cut rose bush peduncles, because it was under its action that the flowers retained their decorative and marketable appearance for the longest time.

The Indian chrysanthemum had an average decorative score of 5 points in the first 7 days based on color and petal shape. Starting from the 11th day, wilting of the petals was observed. On the 14th day, the composition received 1 point for the use of "Floral Preservative", mold appeared on the stems and floral foam and an unpleasant odor was felt.

By day 17, the flowers had completely lost their characteristic varietal color, strong curling of the petals was observed, the peduncles drooped, the edges of the leaf blades dried up and curled on almost 100% of the leaves. The stems became dark in color with signs of decay.

The best preparations for preserving the decorative effect of a composition with chrysanthemum were Chrysal Flower boost, Flora active, and Fleur Eau (Fig. 3).

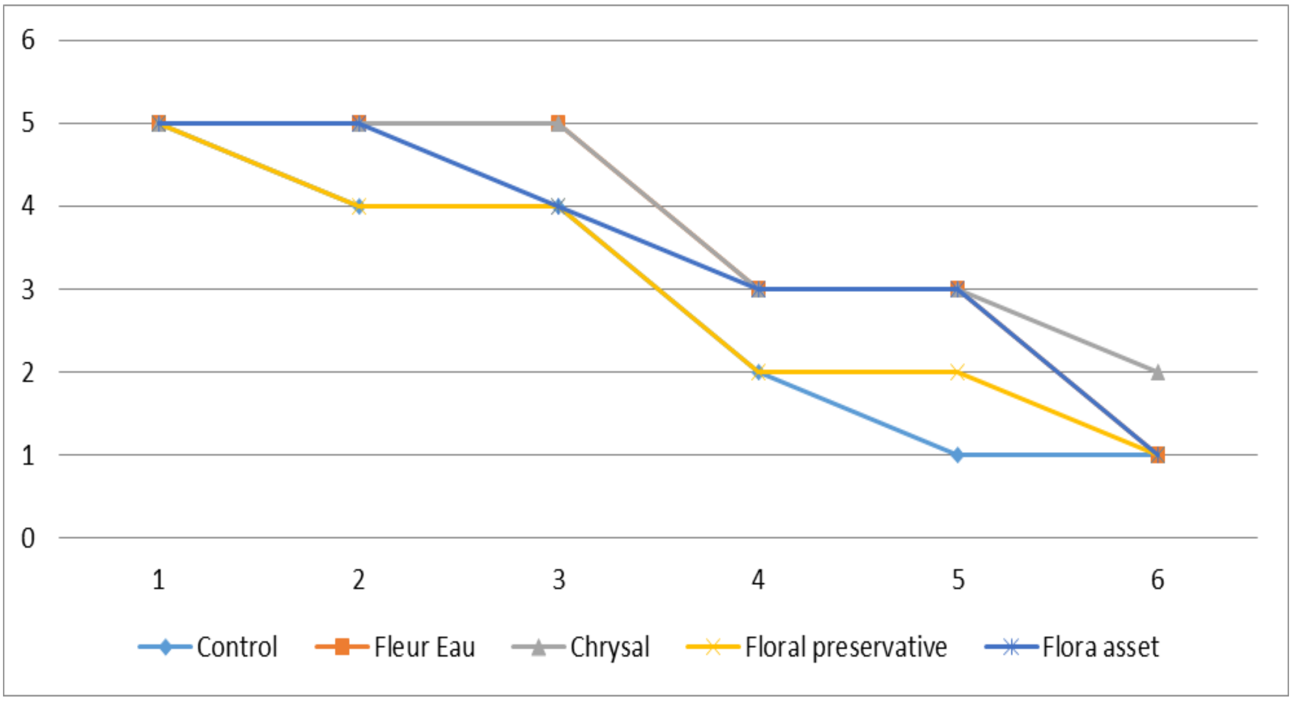

Fig. 3. *Evaluation of the state of turgor of peduncle and stem of rose and chrysanthemum during storage in different preparations, points*

So, in general, we can conclude that the use of preparations to prolong the life of cut flowers has a certain positive effect in the first stages of storage. Soaking a floral sponge in a substrate allows you to preserve the decorative effect of a flower arrangement for 12-26 days, but the first signs of spoilage are observed on day 4-7, regardless of the preparation. The general appearance of flowers at the end of the observations is shown in Fig. 4.

The findings will be of interest to florists and buyers to extend the life and decorativeness of flowers after purchase. Similar research involves a more detailed study of the effect of floral foam on the preservation of cut flowers.

Fig. 4. *Condition of inflorescences of Indian chrysanthemum and rose bush under different storage conditions*

Conclusions. It was found that Chrysal Flower boost was the best among the studied preparations recommended for prolonging the life of flowers after cutting for Indian chrysanthemum and rose bush. The turgor of the peduncle and the condition of the chrysanthemum and rose stem in the first 7 days on the rating scale are 5 points, on the 11th day the darkening of the stem became noticeable, on the 14th day the stem and peduncle acquired signs of darkening (3 points). "Floral preservative" contributed to the formation of mold on the surface of the floral foam, which gave off an unpleasant odor, and the stems began to rot. The use of preparations to prolong the life of cut flowers has a certain positive effect in the early stages of storage. Soaking the floral foam in the substrate allows you to preserve the decorative effect of the flower arrangement for 12-26 days, but the first signs of wilting are observed already on day 4-7, regardless of the use of additional preparations.

REFERENCES

1. Solomakha I., Zhabynska K., Shevchenko K. (2016). Efficiency of appliing of nutrient solution for wet storage of cut carnations remontant. Technical sciences and technologies. №3 (5). S. 210-216
2. Sorokina S.V. (2016). Commodity science of flowers. Kharkiv: KHDUHT. 243 s.
3. Chemistry for cut flowers [Electronic resource]. Available from https://decorize.com.ua/himia-dla-srezannyh-cvetov-podkormka-13264/
4. Yasinskaya A. Cut flowers need care. Electronic resource]. Available from https://zelene.net/interests/pubs/rosliny/poradi-fahivciv-23/zrizani-kviti-potrebuyut-doglyadu.html
5. Ahmad, I., Dole, J. M., Clark, E. M. R., & Blazich, F. A. (2014). Floral foam and/or conventional or organic preservatives affect the vase-life and quality of cut rose (Rosa x hybrida L.) stems. The Journal of Horticultural Science & Biotechnology, 89(1), 41-46. https://doi.org/10.1080/14620316.2014.11513046
6. Begri, F., Hadavi, E., & Nabigol, A. (2014). Positive interaction of ethanol with malic acid in postharvest physiology of cut spray carnation 'white natila'. Journal of Horticultural Research, 22(2), 19-30. https://doi.org/10.2478/johr-2014-0018
7. Chopde N., Dzhadxav Dzh. G., Bxande M. X. (2015). Reakciya kalenduly` na gustotu rastenij dlya proizvodstva srezanny`x czvetov. Arxiv rastenij. 15 (2). 657-660.

8. Dontsova T., Demchenko N. (2004). Green beauty is life: plans and prospects", *Flowers of Ukraine* ["Zelena krasa - ce zhyttja: plany ta perspektyvy", *Kvity Ukrai'ny*]. №. 2, pp. 50-53.
9. Floriculture: Principles and Species by John M. Dole, Harold F. Wilkins. 2005. S 240-268
10. He, S., Joyce, D. C., & Irving, D. E. (2006). Water competition between inflorescences and leaves in cut flowering stems of Grevillea 'Crimson Yul-lo'. The Journal of Horticultural Science & Biotechnology, 81(5), 891-897. https://doi.org/10.1080/14620 316.2006.11512155
11. Junqueira, A. H., & Peetz, M. (2008). Inner market for the products of the Brazilian floriculture: characteristics, trends and recent socio-economic importance. Revista Brasileira de Horticultura Ornamental, 14(1), 37-52. https://ornamentalhorticulture. emnuvens.com.br/rbho/article/viewFile/230/158
12. Junqueira, A. H., & Peetz, M. (2011). Socioeconomic overview of floriculture in Brazil. Revista Brasileira de Horticultura Ornamental, 17(2), 101-108. https://doi.org/10.14295/rbho.v17i2.704
13. Kazaz, S., Kılıç, T., & Şahin, E. G. (2020). Extending the shelf life of cut hydrangea flowers in a vase using preservative solutions. Acta Scientiarum Polonorum, Hortorum Cultus. 19(4), 95-103. https://doi.org/10.24326/asphc.2020.4.9
14. Macnish, A. J., Jiang, C. Z., Negre-Zakharov, F., & Reid, M. S. (2010). Physiological and molecular changes during opening and senescence of Nicotiana mutabilis flowers. Plant Science, 179(3), 267-272. https://doi.org/10.1016/j.plantsci.2010.05.011
15. Nagami X., Sue`naga T., Nakazaki M. (2017). Vozdejstvie pesticidov i sub``ektivny`e simptomy` fermerov, vy`rashhivayushhix srezanny`e czvety`. Journal of rural medicine. 12 (1), 7-11. https://doi.org/10.2185/jrm.2922
16. Negrelle, R., & Anacleto, A. (2012). Bromeliads wild harvesting in State of Paraná. Ciênc. Rural, 42(6), 981-986. https://doi. org/10.1590/S0103-84782012000600005
17. Negrelle, R., & Muraro, D. (2006). Phenological and reproductive aspects of Vriesea incurvata Gaudich (Bromeliaceae). Acta Scientiarum Biological Sciences, 28(2), 95-102. https://doi. org/10.4025/actascibiolsci.v28i2.1011
18. Nguen T. K., i Lim Dzh.X. (2021). Prodlevayut li e`kologicheski chisty`e czvetochny`e konservanty` srok sluzhby` vazy` luchshe, chem ximicheskie rastvory`. Sadovodstvo. MDPI. 2021. https://doi.org/10.3390/ horticulturae 7100415
19. Pattaravayo, R., Ketsa, S., & Van Doorn, W. G. (2013). Sucrose feeding of Cut Dendrobium inflorescences promotes bud opening, inhibits abscission of open flowers, and delays tepal senescence. Postharvest Biology and Technology, 77, 7-10. https://doi.org/10.1016/j.postharvbio.2012.09.014
20. Perik, R. R. J., Razé, D., Ferrante, A., & Van Doorn, W. G. (2014). Stem bending in cut Gerbera jamesonii flowers: Effects of a pulse treatment with sucrose and calcium ions. Postharvest Biology and Technology, 98, 7-13. https://doi.org/10.1016/j. postharvbio.2014.06.008
21. Pietro, J., Mattiuz, B. H., Mattiuz, C. F., & Rodrigues, T. J. (2012). Keeping quality of cut roses cv. Vega in holding solutions. Hortic Bras, 30(1), 64-70. https://doi.org/10.1590/S0102- 05362012000100011
22. Posleuborochnoe kachestvo srezannykh czvetov cinnii, vy`rashhivaemyh pri raznykh urov-nyakh orosheniya i v raznye periody vegetacii. Journal of Selous Chemical Research, 9 (1), 303. https://doi.org/10.5296/jas.v9i1.17996
23. Postharvest Handling and Storage of Cut Flowers, Florist Greens and Potted Plants" by Robert A. Larson. Larson - 2004. [Electronic resource]. Available from https://www.researchgate.net/publication/277732502_Optimizing_Postharvest_Life_of_Cut_Renaissance_Red'
24. Postharvest Physiology and Storage of Tropical and Subtropical Fruits" by Elhadi M. Yahia 2009. [Electronic resource]. Available from
25. Pulido, E., Cuquel, F. L., & Negrelle, R. R. B. (2017). Behavior and postharvest evaluation criteria of Vriesea incurvata Gaudich (Bromeliadaceae) floral scapes. Ornamental Horticulture, 23 (3), 263-269. https://doi.org/10.14295/oh.v23i3.1106
26. Rafdi, H. H. M., Joyce, D. C., Lisle, A., Li, X., Irving, D. E., & Gupta, M. (2014). A retrospective study of vase life determinants for cut Acacia holosericea foliage. Scientia Horticulturae, 180(17), 254-261. https://doi.org/10.1016/j.scienta.2014.10.020
27. Reid, M., & Jiang, C. (2012). Postharvest biology and technology of cut flowers and potted plants. In J. Janek (Eds.), Horticultural reviews (pp. 1-54). Hoboken, John Wiley & Sons. https://doi. org/10.1002/9781118351871.ch1
28. Rubel, F., & Kottek, M. (2010). Observed and projected climate shifts 1901-2100 depicted by world maps of the KöppenGeiger climate classification. Meteorologische Zeitschrift, 19(2), 135-141. https://doi.org/10.1127/0941-2948/2010/0430
29. Sharova O. V., Kurkin V. A. (2007). Flavonoidy` czvetkov kalenduly` lekarstvennoj // Ximiya rastitel`nogo sy`r`ya. (1). 65-68.
30. Tognon, G. B., Amaral, W., Bolzan, R. P., & Cuquel, F. L. (2015). Aesthetic characterization and postharvest performance of Chromolaena laevigata. Acta Horticulturae, 1060, 141-146. https:// doi.org/10.17660/ActaHortic.2015.1060.19
31. Van Doorn, W. G. (1996). Water relations of cut flowers. Horticultural Reviews, 18, 1-85. https://doi.org/10.1002/9780470650608.ch1

32. Verlinden, S., & Vicente García, J. (2004). Sucrose loading decreases ethylene responsiveness in carnation (Dianthus caryophyllus cv. White Sim) petals. Postharvest Biology and Technology, 31(3), 305-312. https://doi.org/10.1016/j. postharvbio.2003.09.010
33. Vexnival S.S., i E`bbi Lord. (2019). Srok godnosti srezanny`x czvetov v vaze - vliyayu-shhie faktory`, metabolizm i organicheskij sostav. Mezhdunarodnyj zhurnal sadovodstva. 3 (6). https://doi.org/10.15406/hij.2019.03.00142
34. Woltering, E. J., Sisler, E. C., Frello, S., & Sriskandarajah, S. (2006). Controlling ethylene responses in flowers at the receptor level. Biotechnology Advances, 24(4), 368-381. https:// doi.org/10.1016/j.biotechadv.2006.01.007
35. Wu, L. Y., Xiao, H., Zhao, W. J., Sun, P., & Lin, J. K. (2016). Effect of green tea extract powder on the vase-life of fresh-cut rose (Rosa hybrida L.) 'Carola' stems. The Journal of Horticultural Science & Biotechnology, 91(3), 279-284. https://doi.org/10.108 0/14620316.2016.1155316
36. Dontsova I. V., Lebedynets V. T, Sapozhnyk D. I. (2024). FRESH CUT FLOWERS: IDENTIFICATION, QUALITY COMPONENTS AND EXPERTISES Herald of Lviv University of Trade and Economics. Technical Sciences. № 37, 19-26. DOI: https://doi.org/10.32782/2522-1221-2024-37-03
37. Ahmad, Iftikhar, Dole, J. M., Clark, E. M. R., & Blazich, F. A. (2014). Floral foam and/or conventional or organic preservatives affect the vase-life and quality of cut rose (Rosa × hybrida L.) stems. The Journal of Horticultural Science and Biotechnology, 89(1), 41-46. https://doi.org/10.1080/14620316.2014.11513046
38. Dole, J. M., Viloria, Z., Fanelli, F. L., & Fonteno, W. (2009). Postharvest Evaluation of Cut Dahlia, Linaria, Lupine, Poppy, Rudbeckia, Trachelium, and Zinnia. *HortTechnology*, *19*(3), 593-600. https://doi.org/10.21273/HORTTECH.19.3.593

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

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

Dudka Anhelina
Doctor of Philosophy, Assistant Professor
ORCID ID: 0000-0001-9444-4339

Sonora Yevhenii,
Master, Assistant
ORCID ID: 0009-0007-8116-2771

Oleksandr Chemerys
Master, Sumy National Agrarian University, Ukraine

INTRODUCTION

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Obtaining planting material of common oak

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Material and Methods

Conditions for conducting research

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

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

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

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

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

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

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

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

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

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

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

Object, subject and research methodology

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

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

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

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

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

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

Results

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

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

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

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

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

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

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

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

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

Our work is devoted to studying the optimal planting dates.

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

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

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

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

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

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

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

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

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

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

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

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

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

a **b**

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

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

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

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

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

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

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

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

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

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

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

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

а б

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

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

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

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

a b

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

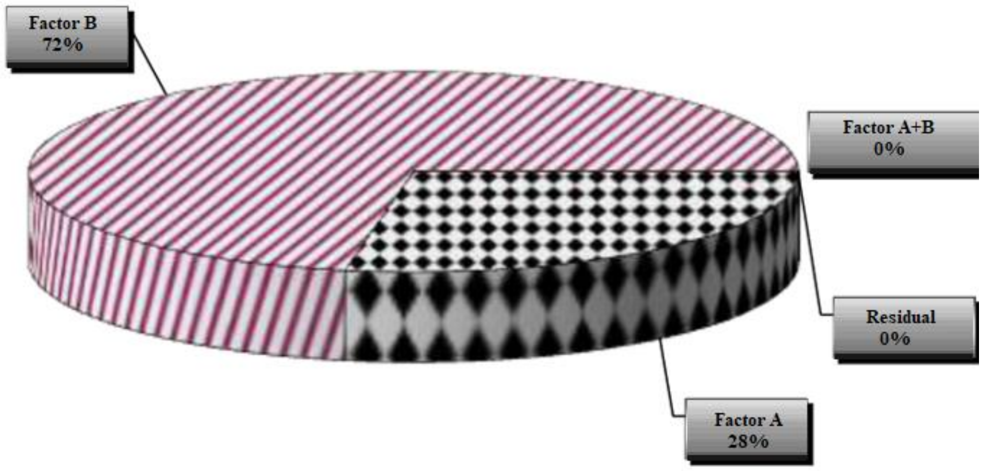

Fig. 7. *The share of influence of factors on the survival of Quercus robur L. in 1-year-old forest cultures created by seedlings with open and closed root systems depending on foliar feeding*

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Conclusions

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

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

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

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

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

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

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

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

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

Suggestions

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

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

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

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

• Use of seedlings with a closed root system.

• Spring sowing of acorns.

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

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

REFERENCES

1. Aas, G. (2000). *Enzyklopädie der Holzgewächse: Handbuch und Atlas der Dendrologie* (A. Roloff, H. Weisgerber, U. M. Lang, B. Stimm, & P. Schütt, Eds.). Wiley-VCH Verlag, Weinheim, 3.
2. Aghai, M.M.; Pinto, J.R.; Davis, A.S. (2014). Container volume and growing density influence western larch (*Larix occidentalis* Nutt.) seedling development during nursery culture and establishment. *New For.* , *45*, 199–213.
3. Appleton, B. L., & Whitcomb, C. E. (1983). Effects of container size and transplanting date on the growth of tree seedlings. *Journal of Environmental Horticulture*, *1*(4), 91-93.
4. Arosa, M. L., Ceia, R. S., Costa, S. R., & Freitas, H. (2015). Factors affecting cork oak (Quercus suber) regeneration: acorn sowing success and seedling survival under field conditions. Plant Ecology & Diversity, 8(4), 519-528.
5. Ayman E. L., Sabagh, Hossain A., Islam M. S., Iqbal M. A., Amanet K., Mubeen M., Erman M. (2022) Prospective Role of Plant Growth Regulators for Tolerance to Abiotic Stresses. *Plant Growth Regulators* . P. 1–38.
6. Bashir, M. A., Rehim, A., Qurat-Ul-Ain Raza, H. M., Raza, A., Zhai, L., Liu, H., & Wang, H. (2021). Agriculture and Environmental Sustainability. *Technology in agriculture*, 311.
7. Belelia, S. O. (2014). The effect of plant growth regulators on germination energy and seed germination of Larix decidua Mill. *Forestry and agroforestry.* 124: P. 76–84.
8. Belous, C. Ю., Marchuk, Yu. M., Boroday, V. V., Likhanov, A. F. (2021). Use of plant-associated bacteria to increase the resistance of *Quercus* L. plants to stressors: collection of abstracts, Kyiv, P. 29–30.
9. Bhatla, S. C.. (2018). Plant growth regulators. *Plant Physio-logy, Development and Metabolism* . P. 559–568.
10. Bossema, I. (1979). The behaviour of the Eurasian Jay, *Garrulus glandarius*, in relation to its environment. *Behaviour, 70*(1).
11. Boyko G. O., Puzrina N. V., Bondar A. O., Hryb V. M. (2021). The influence of microbial agents and biological preparations based on them on the biometric indicators of seedlings Pinus sylvestris L. *Scientific works of the Forestry Academy of Sciences of Ukraine.*. (23). P. 68–78.
12. Bronson, D. R., Meunier, J., Pearson, T. R., & Scanlon, K. (2023). Evaluating effectiveness of girdle-herbicide containment of below-ground spread of oak wilt (Bretziella fagacearum). Forest Ecology and Management, 533, 120816.
13. Buksha, I. F., Bondaruk, M. A., Tselishchev, O. G., Pivovar, T. S., Buksha, M. I., Pasternak, V. P. (2017). Forecast of the viability of Scots pine and Scots oak in the event of climate change in the plains of Ukraine. *Forestry and agroforestry.* 130. P. 146–158.
14. Bunce, R. (1982). *Trees and Their Habitats: An Ecological Guide to Some European Trees Grown at Westonbirt Arboretum*. Forestry Commission Research and Development Division, Edinburgh.
15. Curtu, A. L., Gailing, O., & Finkeldey, R. (2007). *BMC Evolutionary Biology, 7*, 218.
16. Dahm, H. (2006). Role of mycorrhizae in forestry. In Handbook of microbial biofertilizers (pp. 269-298). CRC Press.
17. Danylenko, O. M. (2024). Peculiarities of growth of common oak in cultures created from different types of planting material in the southeastern part of the Left Bank Forest-Steppe. *Scientific Bulletin of UNFU.* 34(5). P. 29–34. https://doi.org/10.36930/40340504
18. Dey, D. C., Jacobs, D., McNabb, K., Miller, G., Baldwin, V., & Foster, G. (2007). Artificial regeneration of major oaks (Quercus) species in the Eastern United States. A review of the literature. *Forest Science.* 54. P. 77–106.
19. Dey, D. C., Jacobs, D., McNabb, K., Miller, G., Baldwin, V., & Foster, G. (2008). Artificial regeneration of major oak (Quercus) species in the eastern United States—a review of the literature. *Forest Science*, *54*(1), 77-106.
20. Ducousso, A., & Bordacs, S. (2003). *EUFORGEN Technical Guidelines for Genetic Conservation and Use for Pedunculate and Sessile Oaks (Quercus robur/Quercus petraea)*. Bioversity International.
21. Faria, T. A., Costa, E., Oliveira, L. C. D., Santo, T. L., & Silva, A. P. D. (2013). Volume of polyethylene bags for development of papaya seedlings in protected environments. *Engenharia Agrícola*, *33*, 11-18.

22. Farkaš, J.; Saniga, M. (2015). Pestovanie Dubových Porastov; Technická univerzita vo Zvolene: Zvolen, Slovakia; p. 62.
23. Aas, G. (1993). *Annales des sciences forestières, 50*, 107s.
24. Ge, M.; Chen, G.; Hong, J.; Huang, X.; Zhang, L.; Wang, L.; Ye, L.; Wang, X. (2012). Screening for formulas of complex substrates for seedling cultivation of tomato and marrow squash. Procedia Environ. Sci., 16, 606–615.
25. Haida Y.I. (2012). Forestry and ecological foundations of conservation and sustainable use of forest genetic resources of the Western region of Ukraine: author's abstract of dissertation for the degree of Doctor of Agricultural Sciences: 06.03.01. Lviv, 40 p.
26. Haratani, H., & Yoshida, T. (2024). Scarification under the canopy of Japanese oak: should pre-harvest treatment coincide with the masting year of acorns?. *Journal of Forest Research*, *29*(6), 450-457.
27. Heiskanen, J. (2013). Effects of compost additive in sphagnum peat growing medium on Norway spruce container seedlings. *New For. 44*, 101–118.
28. Herman, H. (2022). Natural and cultural landscape of Polissya of the Rivne region. *Scientific innovations and advanced technologies.* № 11(13). P. 154–162
29. Jastrzębowski, S., Ukalska, J., & Walck, J. L. (2021). Does the lag time between radicle and epicotyl emergences in acorns of pedunculate oak (Quercus robur L.) depend on the duration of cold stratification and post-stratification temperatures? Modelling with the sigmoidal growth curves approach. *Seed Science Research*, *31*(2), 105-115.
30. Jensen, J., Larsen, A., Nielsen, L. R., & Cottrell, J. (2009). *Annals of Forest Science, 66*, 706.
31. Johnson, O. (2004). Collins tree guide (pp. 464-pp).
32. Jones, E. W. (1959). *Journal of Ecology, 47*.
33. Khurram, S., Burney, O. T., Morrissey, R. C., & Jacobs, D. F. (2017). Bottles to trees: Plastic beverage bottles as an alternative nursery growing container for reforestation in developing countries. *Plos one*, *12*(5), e0177904.
34. Krylov Y. I. (2014). Peculiarities of growth of common oak (Quercus robur L.) in anti-erosion plantations of ravine-beam systems of the Middle Dnieper region. *Forestry and agroforestry.* 124. P. 22–27.
35. Löf, M., Castro, J., Engman, M., Leverkus, A. B., Madsen, P., Reque, J. A., Villalobos, A., & Gardiner, E. S. (2019).Tamm re-view: direct seeding to restore oak (*Quercus spp*.) forests and wo-odlands. *Forest Ecology and Management.* 448.P. 474–489. https://doi.org/10.1016/j.foreco.2019.06.032
36. Longuetaud, F.; Mothe, F.; Santenoise, P.; Diop, N.; Dlouhá, J.; Fournier, M.; Deleuze, C. (2017). Patterns of Within-Stem Variations in Wood Specific Gravity and Water Content for Five Temperate Tree Species. *Ann. For. Sci.* 74. P. 1–9.
37. Lopushniak, V., Bortnik, T., Avhustynovych, M. (2016). The impact of environmentally friendly technologies on the balance of nutrients in gray forest soil of the western Forest-Steppe of Ukraine. *Bulletin of the Lviv National Agrarian University. Agronomy*. (20). P. 146–151.
38. Lukianets, V. A., Rumiantsev, M. H., Musiienko, S. I., Tarnopilska, O. M., Kobets, O. V., Bondarenko, V. V., Yushchyk, V. S. (2023). Experience of artificial reforestation of oak plantations using different methods and types of planting material in the Southeastern Forest-Steppe of Ukraine. *Scientific Bulletin of UNFU*.. 33(1). P. 7–12. https://doi.org/10.36930/40330101
39. Lytsur I., Ткачів С. (2017). The state of forest regeneration in Ukraine as an economic aspect of forest policy. *Economics of natural resources management and environmental protection.* P. 185–193.
40. Manh, V.H.; Wang, C.H. (2014). Vermicompost as an important component in substrate: Effects on seedling quality and growth of Muskmelon (*Cucumis melo* L.). *APCBEE Procedia 8*, 32–40.
41. Marianthi, T. (2006). Kenaf (*Hibiscus cannabinus* L.) core and rice hulls as components of container media for growing *Pinus halepensis* M. seedlings. *Bioresour. Technol. 97*, 1631–1639
42. Martínez de Azagra Paredes, A., Del Río San José, J., Reque Kilchenmann, J., Diez Hernández, J. M., & Sanz Ronda, F. J. (2022). Methods for watering seedlings in arid zones. *Forests*, *13*(2), 351.
43. Matsumoto Y, Oikawa S, Yasumura Y, Hirose T, Hikosaka K. (2008). Reproductive yield of individuals competing for light in a dense stand of an annual. *Xanthium canadense. Oecologia.* 157. P. 185–195.
44. Matushevych L. M., Lakyda P. I. (2014). Leaf surface area index of oak plantations in Eastern Polissya, Ukraine. *Scientific works of the Forestry Academy of Sciences of Ukraine.* (12). P. 148–153.
45. Maurer M. V., Kaidyk O. (2015). Forest restoration in Ukraine in the context of sustainable development: main problems and ways to overcome them. *Forestry and horticulture*, 7. P. 6.
46. Maurer V. M., Pinchuk A. P.(2013). The status and quality of forest restoration work in Ukraine and ways to improve it. *Scientific Bulletin of the National University of Life Resources and Environmental Management of Ukraine. Ser.: Forestry and ornamental gardening.* 187 (1). P. 328–334.
47. Maurer, V. M.; Pinchuk, A. P.; Borshch, M. H. (2015). On the issue of extending the planting dates and increasing the viability of planted plants. *Scientific Bulletin of the National University of Life Resources and Environmental Management of Ukraine. Series: Forestry and Ornamental Horticulture,* 219: P. 157–162.
48. Mazhula O.S. (2008). Key moments in the development of forest seed production in Ukraine. *Forestry and agroforestry.* № 112. P. 132–134.
49. Meusel, H., & Jager, E. (Eds.). (1998). *Vergleichende Chorologie der Zentraleuropäischen Flora* (Vols. I–III). Gustav Fischer Verlag, Jena.
50. Meyer, R. E., & Bovey, R. W. (1980). Control of live oak (Quercus virginiana) and understory vegetation with soil-applied herbicides. *Weed Science*, *28*(1), 51-58.

51. Mikulich, L. O., Prysedskyi, Yu. H., Mashtaler, O. V., Polishchuk, A. V. (2023). The effect of growth stimulants and laser irradiation on the rooting of cuttings *Buxus Sempervirens L. Ukrainian Journal of Natural Sciences*. (6). P. 18–26.
52. Mitchell, A. F., Dahlstrom, P., Sunesen, E., & Darter, C. (1974). *A Field Guide to the Trees of Britain and Northern Europe*. Collins.
53. Mölder, A.; Meyer, P.; Nagel, R.-V. (2019).Integrative Management to Sustain Biodiversity and Ecological Continuity in Central European Temperate Oak (*Quercus robur, Q. Petraea*) Forests: An Overview. *For. Ecol. Manag.* 437. P. 324–339.
54. Monumental Trees. (n.d.). *Monumental Trees*. Available at: https://www.monumentaltrees.com/en/ [Accessed 15 Feb. 2025].
55. Muriuki, J. K., Kuria, A. W., Muthuri, C. W., Mukuralinda, A., Simons, A. J., & Jamnadass, R. H. (2014). Testing biodegradable seedling containers as an alternative for polythene tubes in tropical small-scale tree nurseries. *Small-scale Forestry*, *13*, 127-142.
56. Navarro, F. B., Caño, A. B., Gálvez, C., Kazani, A., Carbonero, M. D., & Jiménez, M. N. (2023). Key factors in direct acorn seeding for the successful restoration of open oak woodlands. Forest Ecology and Management, 546, 121314.
57. Neiko I.S., Monarkh V.V. (2017). Peculiarities of flowering, ovary formation and fruiting of common oak in a clonal plantation in the Vinnytsia region. *Bulletin of the Uman National University of Horticulture.* № 1. P. 101–104
58. Neiko I.S., Smashniuk L.V., Los S.A., Kolchanova O.V., Yelisavenko Y.A. (2015). Dynamics of formation of generative organs of common oak in a clonal plantation in the Vinnytsia region. *Forestry science in the context of sustainable development: materials of the International Scientific-Practical Conference,* 29-30 Sep. 2015 Kharkiv: UkrNDILHA, P. 160–162.
59. Neiko, I. S., Oplakanska, A., Neiko, O. S., Pankova, S. O. (2024). Peculiarities of functioning of forest-seed plantations of common oak (*Quercus Robur*, L) in the conditions of the Right-Bank Forest-Steppe of Ukraine. *Agricultural innovations*, (25). P. 129–133.
60. Oliet, J. A., Vázquez de Castro, A., & Puértolas, J. (2015). Establishing Quercus ilex under Mediterranean dry conditions: sowing recalcitrant acorns versus planting seedlings at different depths and tube shelter light transmissions. New Forests, 46, 869-883.
61. Palamarchuk, V. D., Doronin, V. A., Kolisnyk, O. M., & Alieksieiev, O. O. (2022). Fundamentals of seed science (theory, methodology, practice). *Vinnytsia: Printing House "Druk",*. 392 p.
62. Popov O. F. (2008). Intensification of the cultivation of Scots pine planting material in the south of the Left Bank Forest-Steppe: author's abstract. dissertation. candidate of agricultural sciences: 06.03.01. Kharkiv, Ukrainian Research Institute of Forestry and Agroforestry named after G. M. Vysotsky.
63. Pretzsch, H.; Bielak, K.; Block, J.; Bruchwald, A.; Dieler, J.; Ehrhart, H.-P.; Kohnle, U.; Nagel, J.; Spellmann, H.; Zasada, M. (2013). Productivity of Mixed versus Pure Stands of Oak (Quercus Petraea (M Att.) L Iebl. and *Quercus robur* L.) and European Beech (*Fagus sylvatica* L.) along an Ecological Gradient. *Eur. J. For. Res.* 132. P. 263–280.
64. Prévosto, B., Reque, J., Ripert, C., Gavinet, J., Estève, R., Lopez, J. M.. Guerra, F. (2015). Semer les chênes méditerranéens (Qu-ercus ilex, Quercus pubescens): pourquoi, comment et avec quelle réussite? *Forêt Méditerranéenne,*. 36 (1). P. 3–16
65. Purba, C.Y.C.; Dlouha, J.; Ruelle, J.; Fournier, M. (2021). Mechanical Properties of Secondary Quality Beech (*Fagus sylvatica* L.) and Oak (*Quercus petraea* (Matt.) Liebl.) Obtained from Thinning, and Their Relationship to Structural Parameters. *Ann. For. Sci.* 78. P. 1–11.
66. Rafalska L. P. (2015). Technology of growing planting material of downy oak (Quercus pubescens Willd.). *Scientific Bulletin of the National University of Life Resources and Environmental Management of Ukraine. Series: Forestry and Ornamental Horticulture.* 229. P. 100–104.
67. Raspina S., Didenko M., Belai Yu., Horoshko V., Harmash A.(2022). The influence of growth stimulants on the survival and growth of Scots pine in forest cultures of the Slobozhansky forest-vegetation district of Ukraine. Scientific works of the Forestry Academy of Sciences of Ukraine, 24. P.120–128. https://doi.org/https://doi.org/10.15421/412210
68. Reho, M.; Vilček, J.; Torma, S.; Koco, Š.; Lisnyak, A.; Klamár, R. (2022). Growing of the Containerized Seedlings of English Oak (Quercus robur L.) to Establish Sustainable Plantations in Forest-Steppe Ukraine. *Forests.* 13. 1359. https://doi.org/10.3390/f13091359 \
69. Robert, E.M.R.; Mencuccini, M.; Martínez-Vilalta, J. (2017). The Anatomy and Functioning of the Xylem in Oaks. In *Oaks Physiological Ecology. Exploring the Functional Diversity of Genus Quercus L.*; Springer: Berlin/Heidelberg, Germany. pp. 261–302.
70. Roloff, A., Weisgerber, H., Lang, U. M., & Stimm, B. (2010). *Bäume Mitteleuropas: Von Aspe bis Zirbelkiefer. Mit den Porträts aller Bäume des Jahres von 1989 bis 2010*. Wiley-VCH.
71. Romanchuk, L. D., Didenko, P. V. (2022). The effect of the drug Bioecofunge-S on the growth and development of Scots pine planting material (*Pinus sylvestris L.*). *Agrobiology*, 198.
72. Rumiantsev M. N., Danylenko O. M., Tarnopilskyi P. B., Yushchyk V. S., Mostepaniuk A. A. (2022). The effect of plant growth stimulants on biometric indicators and mass of one-year-old holm oak seedlings with a closed root system in the conditions of the Southeastern Forest-Steppe of Ukraine. *Scientific Bulletin of the National Technical University of Ukraine.* 32(1). P. 13–19. https://doi.org/10.36930/40320102

73. Sanchez, P. A., Buresh, R. J., & Leakey, R. R. (1997). Trees, soils, and food security. Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences, 352(1356), 949-961.
74. Savill, P. S. (2013). *The Silviculture of Trees Used in British Forestry*. CABI.
75. Savushchyk M.P., Khromuliak O.I., Shlonchak H.A., Yashchuk I.V. (2020). The influence of plant growth regulators on the growth of Scots pine seedlings in open ground (Kyiv Forest Research Station). *Forestry and forest reclamation.* 136. C. 78–82. https://doi.org/10.33220/1026-3365.136.2020.78
76. Shalovylo, Yu. I. (2019). Bacterial bioinoculation as a method of increasing morphometric parameters of one-year-old Scots pine seedlings. *Scientific Bulletin of the National Technical University of Ukraine.* 29.9. P. 22–26.
77. Shust V. V. (2016). Introduced species of pine trees in the conditions of the Radyvyliv district of the Rivne region. Recommended for publication by the meeting of the Department of Methods of Extracurricular and Extracurricular Work of the National Ecological and Naturalistic Center for Student Youth 2016. (Minutes No. 2 of March 10, 2016), 93 p.
78. Singh, P., Bakshi, M., & Anmol, A. (2024). Natural plant extracts as a sustainable alternative to synthetic plant growth regulators: A review. *International Journal of Advanced Biochemistry Research*, *8*(7), 281-287.
79. Sinnett, D., Poole, J., & Hutchings, T. R. (2008). A comparison of cultivation techniques for successful tree establishment on compacted soil. Forestry, 81(5), 663-679.
80. Smolia, A. L., Kapustian, A. V., & Taran, N. Yu. (2015). The condition of centuries-old trees - natural monuments of local importance in the current ecological situation of the Koncha-Zaspa recreational zone. *Scientific Bulletin of the National University of Life Resources and Environmental Management of Ukraine. Series: Forestry and Ornamental Horticulture.* 229. P. 313–323.
81. Stein, W.I.; Edwards, J.L.; Tinus, R.W. (1975). Outlook for container-grown seedling use in reforestation. J. For., 73, 337–341.
82. Storozhuk V. F. (2016). General assessment of the state of forest management in Ukraine. Kyiv, 78 p.
83. Tkach, V. P., Los, S. A., Tereshchenko, L. I., Torosova, L. O., Vysotska, N. Yu., Volosianchuk, R. T. (2013). Current status and prospects for the development of forest breeding in Ukraine. *Forestry and agroforestry.* (123). P. 3–12.
84. Tkach, V., Rumiantsev, M., Kobets, O., Luk'yanets, V., Musienko, S. (2019). Ukrainian plain oak forests and their natural regeneration. *Forestry Studies*. *7 1* (1). P. 17–29.
85. Tokar O. Ye.; Korol M. M.; Husti M. I. (2021). Assessment of carbon stocks in the phytomass of forest stands in protected areas of the Ukrainian Carpathians. *Scientific Bulletin of the National Technical University of Ukraine.* 31.5. P. 42–46.
86. Tsakaldimi, M.; Zagas, T.; Tsitsoni, T.; Ganatsas, P. (2005). Root morphology, stem growth and field performance of seedlings of two Mediterranean evergreen oak species raised in different container types. Plant Soil, 278, 85–93.
87. Tsakaldimi, M.; Zagas, T.; Tsitsoni, T.; Ganatsas, P. (2005). Root morphology, stem growth and field performance of seedlings of two Mediterranean evergreen oak species raised in different container types. Plant Soil, 278, 85–93.
88. USDA NRCS. (2015). *The PLANTS database*. National Plant Data Team, Greensboro, USA. Available at: http://plants.usda.gov [Accessed 16 Feb. 2025].
89. Veijalainen, A.M.; Heiskanen, J.; Juntunen, M.L.; Lilja, A. (2008). Tree-seedling compost as a component in Sphagnum peat-based growing media for conifer seedlings: Physical and chemical properties. Acta Hortic., 779, 431–438.
90. Veijalainen, A.M.; Juntunen, M.L.; Heiskanen, J.; Lilja, A. (2007). Growing Picea abies container seedlings in peat and composted forest-nursery waste mixtures for forest regeneration. Scand. J. For. Res., 22, 390–397.
91. Yang, Y., & Yi, X. (2022). Nondormant acorns show higher seed dispersal effectiveness than dormant ones. *Forests*, *13*(6), 881.
92. Yavorovskyi, P. P., Seheda, Yu. Yu. (2015). Creation of forest plantations with planting material of common oak (*Quercus robur* L.) grown in nurseries with a closed root system. *Forestry and horticulture*. (7).
93. Yavorovskyi, P. P., Seheda, Yu. Yu. (2019). An effective method for creating forest cultures of common oak (*Quercus robur* L.) in the Right-Bank Forest-Steppe of Ukraine. *Forestry and landscape construction*. 16.
94. Zadworny, M., Jagodziński, A. M., Łokomy, P., Ufnalsi, K., & Oleksyn, J. (2014). The silent shareholder in deterioration of oak growth: common planting practices affect the long-term response of oaks to periodic drought. *Forest Ecology and Management.* 318. P. 133–141. https://doi.org/10.1016/j.foreco.2014.01.017
95. Zdioruk, N., Dascaliuc, A., Ralea, T., & Platovschii, N. (2021). The effectiveness of physiological methods for optimizing work on the arrangement and restoration of oak forests. In AgroSym (pp. 118-125).

PECULIARITIES OF GROWING *QUERCUS RUBRA* L. IN THE CONDITIONS OF SUMY REGION

Horbas Serhii
Candidate of Agricultural Sciences, Associate Professor of the Department of Garden Design and Forestry, Head of the Educational Laboratory of Horticulture and Viticulture
ORCID ID: 0000-0003-3768-8833

Kytaihora Anton
Master of Industrial Training of the Educational Laboratory of Horticulture and Viticulture, PhD Sumy National Agrarian University, Ukraine
ORCID ID: 0009-0008-0459-3508

Koval Serhiy
Ph.D., Sumy National Agrarian University, Ukraine
ORCID ID: 0009-0004-4678-3298

Quercus rubra L. is a North American introduction and was first introduced to Europe in 1691. However, this variety began to be actively introduced into forest crops from the end of the XIX to the beginning of the XX century. In Ukraine, Red Oak first appeared in the Kharkiv region in 1809. The introducer was introduced into the forest culture of Galicia much later, in 1888, after a long discussion among foresters [12, 15].

Relevance of the topic. The study of *Quercus rubra* cultivation peculiarities is due to the importance of this species in the formation of forest ecosystems, its economic and ecological significance. Red oak is a valuable tree species used in construction, furniture industry, and is also important for reforestation of degraded lands and formation of sustainable landscapes. Due to its decorative qualities, it is also widely used in urban and park landscaping. The aim of the study is to investigate acorn germination and determine the optimal germination conditions (temperature, humidity, soil type).

Research objectives:

- Determine the effect of soaking acorns in water of different temperatures on germination.
- Determine the effect of growing *Quercus rubra* seedlings under reduced watering conditions.
- To study the cultivation of *Quercus rubra* seedlings in different types of soil (sand, black soil).

Scientific novelty of the experiments: The study of the little-explored aspects of acorn germination and development in different environmental conditions. The study of the effect of soaking acorns in water of different temperatures allows us to determine the optimal temperature conditions that stimulate seed germination and activate its metabolic processes.

This helps to understand the mechanisms of oak seed adaptation to environmental changes. Experiments with reduced watering help to identify the resistance of young plants to water deficit and analyze their ability to adapt to drought conditions.

The results of such studies can become the basis for the selection of drought-resistant oak species and the development of effective methods for its cultivation in the face of climate change.

Growing acorns in different types of soil, such as sand or black soil, allows us to assess the impact of soil characteristics on plant development. This provides new knowledge about the adaptation of oak to unfavorable soil conditions, which is of practical importance for reforestation of degraded areas.

General characteristics of Quercus rubra L.

Quercus rubra L., or red oak, is a species of deciduous tree in the beech family (*Fagaceae*), which is common in North America and naturalized in many regions of Europe, including Ukraine.

Botanical classification: Family: *Fagaceae*, genus: *Quercus* (Oak), species: *Quercus rubra* (Red Oak).

Appearance: A tall tree that reaches a height of 20-25 m, in favorable conditions it can grow up to 30 m or more. The crown is broadly ovoid or rounded, conical at a young age. The bark of young trees is smooth, light gray; with age it becomes darker and forms shallow cracks. Leaves are large (10-25 cm long), simple, alternate, with 7-11 sharply toothed lobes, lighter below, often slightly pubescent. Autumn color is bright red or crimson, which adds to the decorative effect[1].

Flowering and fruits: In May, at the same time as the leaves bloom. Flowers are unisexual, inconspicuous, greenish in color. Male flowers are collected in earrings, female flowers are single or in pairs.

Acorns are ovoid, up to 2.5 cm long, covered with a thin cap that covers about a quarter of the fruit. They ripen two years after flowering.

Habitat and ecological features: East and center of North America. Widely cultivated and naturalized in Europe and Asia. It grows well on acidic or slightly acidic soils. Sensitive to waterlogging, but relatively resistant to drought. Shade-tolerant at a young age, becomes light-requiring over time.

Importance: Often planted in parks, gardens, as an urban tree due to its beautiful autumn color. The wood is strong, with a beautiful texture, used in the furniture industry, for parquet, veneer.

It differs from other types of oaks in its thinner bark, bright red color of autumn leaves, and rapid growth.

This species is widely used in landscaping, forestry, and ornamental gardening[4].

Quercus rubra L. (red oak) is of great economic importance due to its ecological, decorative and economic properties. It is widely used in various fields: from forestry to urban landscaping.

Physical properties: Durable, hard, medium-density wood (0.56-0.75 g/cm^3), resistant to cracking and deformation, has an attractive texture and reddish-brown hue.

It is used in the furniture industry for the manufacture of tables, cabinets, chairs, beds. parquet and flooring, for decorative finishing of furniture, construction materials: beams, stairs, trim, joinery.

Forestry: A fast-growing species: Red oak grows faster than common oak (*Quercus robur*), so it is valuable for reforestation.

Profitability: Acorns from red oak ripen faster, making reforestation easier.

Possibility of export: Red oak is a popular commodity on the world market.

Landscaping: It is used for parks, alleys, gardens, bright red autumn leaves add decorative effect. It tolerates gas pollution, soil compaction and dry air. It helps to strengthen slopes due to its powerful root system[4, 16].

As a tapeworm. Oak is planted separately, at a considerable distance from other plants. It is usually placed on open lawns or lawns, making it the main element of the garden composition. Given enough free space around it, the oak develops an even and spreading crown.

In linear plantings. When creating linear plantings, the distance between trees should be increased, taking into account the size of the crown of an adult oak. For alleys, the average distance between seedlings should be 10-20 meters. Oaks are often planted along footpaths or driveways, using two rows of plantings on both sides.

As protection from the wind. Thanks to its powerful root system, oak is resistant even to strong winds. In open and windy areas, you can plant several mature trees that will effectively protect the area from storms and gusts of wind. As part of a landscape composition. When creating a forest landscape, oak is the main accent. It should be placed so that it receives enough light and the neighboring plants consist mainly of shade-tolerant species.

Ecological significance: Acorns are a source of food for birds (jays, woodpeckers), small mammals (squirrels, deer, bears). Helps to clean the air and create favorable conditions for other plants. Creates a habitat for many species of insects and animals.

Energy use: The wood burns well, giving off a lot of heat. It is used to make high-quality charcoal.

Pharmaceuticals and folk medicine: The bark and acorns contain tannins that have anti-inflammatory, astringent and antiseptic properties. They are used to treat diarrhea, skin inflammation, and bleeding.

Fodder base: Acorns are used to feed pigs and wild animals in forestry.

Advantages and disadvantages in use: Advantages: Rapid growth and unpretentiousness, high decorative value, high quality wood, resistance to urban conditions.

Disadvantages: Invasiveness: In some regions (e.g., Europe), red oak displaces native species. Acorns of red oak are bitter, which reduces their value as fodder for some animals.

Quercus rubra L. combines aesthetic, practical and environmental qualities, which makes it an important component in many sectors of the economy[18, 21]. The main tree species used in agriculture are oak, ash, maple, and pine. The estimated volume of logging for the main purposes is 36,600 cubic meters per year.

The area of clear-cutting is 90-100 hectares per year, with additional thinning and sanitary felling of 750-770 hectares per year. The total stock of forest trees is 5.97092 million m3. The average volume of forest land per hectare is 272 cubic meters. The average capacity of ripe and overripe water per 1 hectare is 338 cubic meters. The average age of the plantations is 70 years. Scots pine and common oak are the main forest tree species [34].

Natural and climatic conditions of the forestry. According to the forest vegetation zoning, the territory of the forestry belongs to the forest-steppe zone - the Left Bank hayfields. The territory of the forestry has a mild continental climate with relatively mild winters and warm summers. The main climatic indicators are shown in the table. 1.

Table 1. Climatic indicators of the forestry area

Name of the indicator	**Unit of measurement**	**Value**	**Date**
Air temperature average annual absolute maximum absolute minimum	 ^{0}C ^{0}C ^{0}C	 +6,4 +37 -34	 July January
Amount of precipitation per year	days	518	
Length of the growing season	days	200	
Last frosts in spring			02.06
The first frost in the fall			05.09
Average date of river freezing			December
Average flood start date			March
Snow cover capacity time of appearance time of sunrise in the forest	 cm	 22	 10.12 24.03
Depth of soil freezing	cm	40–50	
Direction of prevailing winds winter spring summer autumn	 rhumb rhumb rhumb rhumb	 W,S N,SE W,NW N,NW,S,S	
Average wind speed winter spring summer autumn	 m/s m/s m/s m/s	 4,7–5,1 4,0–4,8 3,4–3,5 3,9–4,6	
Relative air humidity	%	79	Maximum January, minimum May

Climatic factors that negatively affect the growth and development of plantations include:
- Frosts in late spring and early fall.
- Strong southeast winds in spring.
- Development of erosion processes.
- Snow and heavy rain melt quickly.

Soil conditions of the forestry. The main soil-forming rock in the forest lands is forest loam, which makes up 59.1%. Under the influence of the peat process, the most humus and complete structural soil (gray forest soil) is formed on it.

Main types of soils (%):
- gray forest - 44.5%;
- podzolized chernozems - 22.7%;
- marsh - 15.9%;
- meadow - 6.2%;

Soil type, an important part of the forest area is located in difficult topographic conditions, in the formation of which morphological structures of erosion and accumulation play a major role.

Erosion processes of varying intensity occur throughout the territory, associated with the climatic and soil conditions of the active area. The most typical are planar and linear water erosion associated with the presence of gullies. Water erosion is widespread on the lands of forestry and other users near forestry enterprises.

The soil is sufficiently drained. The water table in the floodplains ranges from 1-3 meters to 10-15 meters. Most soils are classified as fresh in terms of moisture content. The process of waterlogging is observed in all forestries on small areas.

The area where the forestry is located belongs to the agro-industrial districts of the region with developed agriculture. The leading sectors of the national economy are the food industry, agriculture, production of grain and industrial crops. The agricultural land available in the forest fund is used for the needs of the local population. Forestry plays a significant role in the district's economy. The main directions of its development are the integrated use of forestry, reforestation, protection and recreation measures, which ensures the rational use of forest resources. Other forest uses include beekeeping, birch sap harvesting, and the collection of mushrooms, berries, and medicinal raw materials by the local population [41].

The main activities of the forestry include integrated logging of various types, such as clear-cutting, selective sanitary, gradual and combined. Each of these methods has its own characteristics and is applied depending on the age, condition of the stands and environmental conditions. Clear-cutting involves the complete removal of trees in a certain area and subsequent restoration of forest cover, while selective sanitary felling is aimed at removing damaged, diseased or dead trees, which helps to strengthen the overall sustainability of the forest.

In addition to timber harvesting, an important part of the forestry's work is the maintenance of the forest stock and the restoration of its ecosystem. This includes felling to maintain young plantations, rehabilitating damaged areas, planting new trees and creating protective forest belts. Due to active deforestation in previous years, special attention is paid to reforestation and biodiversity enhancement measures.

In the recent period, forestries have been actively implementing measures to collect and utilize logging residues, which helps reduce the risk of fire and improve the sanitary condition of forests. Depending on the type of harvesting, wood residues can be used to make fuel briquettes, mulch the soil, or decompose, which contributes to the natural enrichment of the soil with organic matter. In some cases, controlled burning is used to eliminate potential sources of pests and diseases.

Forestries are also actively involved in implementing reforestation programs that cover a large part of Sumy region. These programs involve large-scale tree planting, including valuable species that are well adapted to local climatic conditions. These programs involve not only forestry workers, but also volunteers, environmentalists, and school forestry students, which helps to foster an environmental culture among young people.

Among the main problems of forest management in the region are the threat of fires, damage to plantations by insect pests and the spread of tree diseases. Forest fires become especially relevant during dry periods, which requires constant monitoring and preventive measures, such as creating firebreaks, monitoring the state of forests with unmanned aerial vehicles, and conducting public awareness campaigns. Tree damage by pests such as bark beetles, fungal and viral diseases significantly worsens the condition of forests, which requires timely response, biological control and the use of modern protection methods.

Sumy Oblast forestry continues to work to increase the resilience of forest ecosystems by implementing modern methods of management, biodiversity conservation and adaptation of forest plantations to climate change.

The main activities of the forestry, as well as other structural divisions of the forestry, include the following areas:

Forestry performs various types of felling:

The main activities of a forestry, as well as other structural subdivisions of forestry, include the following areas:

1. Harvesting The forestry performs various types of harvesting:

- Clear-cutting: used in areas of mature forest to completely remove timber. This method is often used to renew forest plantations.
- Sanitary felling: carried out to remove diseased, damaged, dead or hazardous trees. The goal is to prevent the spread of disease and maintain ecological balance.
- Selective felling: removes only individual trees, leaving the bulk of the stand intact to preserve biodiversity.

Harvesting includes measures to collect harvesting residues for their utilization: burning or leaving them to rot.

2. Reforestation

- Afforestation: planting of tree seedlings on the sites of logging or degraded land.
- Forest crop maintenance: regular weed removal, thinning and fertilization of young plantations.
- Reforestation programs: the area under reforestation is constantly growing in the region, contributing to environmental sustainability.

3. Forest protection

- Fire prevention: creation of mineralized strips, fire control and fire prevention by raising awareness of the local population.
- Pest and disease control: monitoring and application of biological and chemical methods of forest pest control.

4. Rational use of forest resources

- Harvesting of different types of wood, including:
- Round timber for construction;
- Firewood for heating;
- Wood for technological needs.

Involvement of wood in secondary processing or sale, ensuring economic efficiency of the farm.

5. Environmental monitoring Forestry monitors the condition of soils, water resources and the impact of climate change on forest plantations. Modern methods of analysis are used to respond effectively to challenges.

6. Environmental education

- Organizing excursions for schools and local communities.

- Conducting public awareness campaigns aimed at preserving natural resources and ecosystems.

Problems and challenges:

- Frequent human-caused fires pose a threat to forests.
- Problems with pests and tree diseases, which are sometimes difficult to control.
- The need to modernize forest management technologies to improve environmental friendliness.

This activity is aimed at sustainable forestry development and preservation of the natural environment in the region.

Research on growing seedlings

To create the conditions for conducting research on growing seedlings, we used the forest land of the forestry on a plot of forestry land.

Preparing the site for sowing oak acorns

Site preparation is an important stage that affects the success of germination and further growth of seedlings. The main preparation steps include analyzing the area, tilling the soil, creating optimal conditions and protecting future seedlings:

- Site selection: open area, well-lit by the sun.
- Optimal soil type: sandy-clay or sandy loam with a neutral or slightly acidic reaction (pH 5.5-6.5).
- Avoid swampy soils: it is important that water does not stagnate on the surface, as this can cause rotting of the seeds.

Cleaning and preparing the soil:

- Clearing: removal of weeds, roots and plant residues.
- Pre-sowing treatment: in case of dense grass vegetation, loosening or plowing.
- Deep loosening: 20-30 cm to provide oxygen access to the roots.
- Surface leveling: to prevent water stagnation.
- Furrow formation: depth 5-8 cm, distance between furrows 15-20 cm.

Soaking acorns in water of different temperatures

This method is widely used to prepare oak seeds for germination or stratification. The temperature regime of soaking can significantly affect the rate of swelling of the acorn shell, the activation of internal biological processes and the final germination of seeds.

The purpose of soaking acorns.

1. Removal of poor quality seeds

- Empty or damaged acorns tend to have less weight, so they float to the surface when soaked in water.
- Acorns that remain on the bottom are healthy and have a high chance of successful germination.

2. Accelerate seed swelling

- Soaking allows the acorns to absorb moisture faster, which helps to activate the processes inside the embryo.
- This is especially important for acorns that have been stored in dry conditions or have a thick shell.

3. Stimulation of germination

- Using water of different temperatures can mimic natural conditions, which promotes better seed germination.
- Contrast soaking or treatment with warm water can accelerate the release of seeds from dormancy.

Methods of acorn soaking.

1. Cold water (10-15 °C).

- Duration: 24-48 hours.

- Advantages:
• Creates natural conditions for seeds.
• Helps to separate empty and damaged acorns.
• Effective method for preparation before stratification or sowing.
- Recommended for:
• Testing seed viability before planting.
• Seeds that will undergo long-term stratification.

2. Warm water (30-40 °C)
- Duration: 12-24 hours.
- Advantages:
• Accelerates the swelling process.
• Activates internal growth processes.
• Suitable for hard-shelled acorns.
- Recommended for:
• Seeds that have been stored for a long time.
• Cases when it is necessary to shorten the preparation period before planting.

3. Contrast soaking (alternating temperatures)
- Process:
• First soak in warm water (40 °C) for 2-3 hours.
• Then rapid cooling to 10-15 °C.
• Repeat the cycle 2-3 times.
- Advantages:
• Simulates natural conditions of temperature change, which activates the germ.
• Improves the germination rate.
• Helps to overcome the deep dormant period of seeds.
- Recommended for:
• Acorns that germinate slowly or have a hard shell.
• Seeds that need additional stimulation before sowing.

4. Hot water (50-60 °C)
- Duration: 10-15 minutes.
- Advantages:
• Disinfects seeds from fungi, bacteria and parasites.
• Helps to break down the outer shell if it is too hard.
- Recommended for:
• Seed treatment before sowing in difficult conditions (clay or wetlands).
• Killing pests that may be inside the acorn.

Additional recommendations

1. Preparation before soaking
• Clean the acorns from the remaining caps.
• Check them for damage or mold.

2. Choosing the right water
• Use clean water without chemical impurities.
• If soaking lasts longer than 24 hours, change the water every 12 hours.

3. Further steps after soaking
• Air dry the acorns before stratifying or sowing.
• If the acorns are to be stratified, they should be mixed with moist sand or peat and stored in a cool place.

These methods can significantly improve acorn germination and increase their viability before planting in the wild or in nurseries.

Growing oak seedlings with reduced watering

Growing oak seedlings in conditions of limited water supply requires a careful approach to ensure the successful growth and development of young plants. It is important to properly organize watering, soil care, and monitoring the condition of the seedlings.

Key steps and recommendations.

1. Watering in the initial stages

- After planting, provide moderate but regular watering to keep the soil moist, but not too wet.
- More frequent watering is necessary in the first 2-3 months, as young seedlings do not yet have sufficiently developed root systems to extract water from deeper soil layers.
- Avoid overwatering as this can lead to root rot and fungal diseases.

2. Adapting to reduced watering

- The frequency of watering is gradually reduced after 3-6 months, providing water only once a week.
- Watering should be deep to stimulate root development and ensure plant resilience in dry conditions.

3. Mulching

- Covering the soil surface with a layer of mulch (straw, sawdust, wood chips) helps to reduce moisture evaporation, protect the roots from overheating and improve soil structure.
- The optimal thickness of the mulch layer is 5-7 cm.

4. Controlling the development of seedlings

- Young oaks growing under reduced irrigation gradually develop a deep root system that helps them extract moisture from the deeper soil layers.
- If the seedlings are planted in a group, thinning should be done, leaving the strongest specimens and removing the weaker ones.

Growing red oak (Quercus rubra) in different soil types

The growth of red oak seedlings depends largely on the physical and chemical properties of the soil, including fertility, moisture retention, aeration, acidity, and structure.

Sandy soils

Advantages:

- Good aeration.
- Less risk of water stagnation, which prevents root rot.

Disadvantages:

- Low fertility due to insufficient humus content.
- Fast drying and poor moisture retention capacity.

Recommendations:

- Regular application of organic fertilizers (humus, compost) to increase the level of humus.
- Addition of clay particles to improve moisture retention capacity.

Black soil.

Advantages:

- High fertility due to high humus content.
- Good water retention capacity.

Disadvantages:

- In case of poor drainage, water stagnation is possible, which can negatively affect the root system.
- Sometimes requires acidity correction, as chernozems can be alkaline.

Recommendations:

- Organize a drainage system to prevent water stagnation.
- Adding acidic materials (peat, iron sulfate) in case of high soil alkalinity.

Expected results.

- In sandy soil, growth will be slower due to nutrient deficiencies, but the tree will have better drought resistance.
- In chernozem, seedlings develop faster, but the moisture level needs to be controlled to avoid root rot.

Thus, red oak can be successfully grown on both types of soil, but it is necessary to take into account the characteristics of each type and adapt agrotechnical measures to the conditions of the area [6].

Determining the effect of soaking acorns in water of different temperatures on germination

Acorns of red oak (Quercus rubra) have certain optimal conditions for germination. To germinate, acorns require temperatures in the range of 1-5°C, which mimics natural winter conditions and helps to overcome physiological dormancy. High humidity is a prerequisite for germination, and the ideal air humidity for this process is approximately 80-90%. At the same time, acorns do not need direct sunlight to germinate, but they should be in a dark place with sufficient humidity.

Acorns can germinate on a variety of soil types, but they do best on light, well-drained soils with a high content of organic material. Such soils provide sufficient oxygen and water for active sprouting [29, 36].

The importance of soaking acorns.

Acorn soaking is an important step in preparing acorns for germination or stratification. This procedure helps to improve the ability of seeds to germinate, accelerate swelling and activate internal biological processes. In addition, soaking helps to identify acorns unsuitable for germination: damaged or hollow specimens float to the surface of the water.

Effect of water temperature on the soaking process.

Table (3.1) shows the methods of soaking at different temperatures - from cold (10-15 °C) to hot (50-60 °C). This parameter determines the rate of swelling and the activation of biochemical processes in the seeds. Studies show that water temperature has a significant impact on the rate of shell swelling and root yield. Too high a temperature can damage the embryo, while too low a temperature can significantly prolong the swelling process.

Duration of soaking.

The soaking time varies depending on the water temperature:

- Hot water (50-60 °C) - 10-15 minutes. Used to sterilize seeds from fungal infections and pests.
- Warm water (30-40 °C) - 3-6 hours. Accelerates swelling and stimulates germination.
- Cold water (10-15 °C) - 24-48 hours. Simulates natural conditions and promotes natural swelling and preparation for stratification.

Purposes of soaking

The acorn soaking procedure can have different purposes:

- Natural swelling before stratification to accelerate the germination process.
- Stimulation of germination by creating optimal water conditions.
- Sterilization to destroy potential pathogens that can cause seed decay.

Factors affecting soaking efficiency

Soaking efficiency depends on:

- The condition of the acorn shell (thin or thick). Thick-skinned acorns require a longer soaking time for water to penetrate.
- Storage time - freshly harvested acorns germinate faster than those that have been stored for a long time.
- The presence of infection - if acorns contain fungal infections, hot soaking can be useful for disinfecting them.

- Stressful conditions for sowing - under unfavorable conditions such as dryness or cold, pre-soaking can increase the chances of successful germination.

Soaking acorns in water of different temperatures is an effective method of preparing seeds for germination. The choice of the optimal temperature and time of soaking depends on the specific goals (germination, stratification, sterilization) and physiological characteristics of the seeds. Compliance with the correct soaking conditions significantly increases acorn germination, ensuring their active growth and development.

Table 2. Acorn soaking methods with germination results (50 pcs.)

Method	Water temperature	Duration	Purpose	When to use	Sown	Germination result
Cold water	10–15 °C	24-48 hours	Natural swelling of seeds, preparation for stratification or sowing	For fresh acorns with thin shells	50 pcs.	40 pieces germinated (80%)
Warm water	30–40 °C	12-24 hours	Accelerating the swelling of the shell	For hard-shelled acorns or those that have been stored for a long time	50 pcs.	45 pieces germinated (90%)
Contrast soak	40 °C → 10–15 °C	Hot water: 2-3 hours Cooling: arbitrary time	Simulation of natural temperature changes, stimulation of germination activity	To improve germination in near-natural conditions	50 pcs.	42 pieces germinated (84%)
Hot water	50–60 °C	10-15 minutes	Seed sterilization, preparation for sowing in adverse conditions	In case of seed or soil infestation by pests or diseases	50 pcs.	35 seeds germinated (70%)

The best result (90% germination rate) was achieved with the warm soaking method. Cold water is effective for fresh acorns with thin shells (80% germination).

Contrast soaking stimulates a good result (84%) and is suitable for simulating natural conditions.

Hot water provides sterilization, but reduces germination (70%), due to possible stress to the seeds.

The dependence of germination of red oak (*Quercus rubra*) acorns on the type of soil (sandy or black soil) and the method of irrigation is shown in Table 3.

For the experiment, 50 acorns were sown in each combination of conditions. The main goal is to determine how different combinations of factors affect the percentage of germination of seedlings.

Natural moisture: dependence on natural precipitation, without additional intervention.

Drip irrigation: regular and targeted supply of water directly to the root zone.

Surface irrigation: irrigation in which water is distributed over the soil surface.

Automated irrigation: the use of technology to maintain optimal moisture levels.

Table 3. Acorn germination of Quercus rubra L. depending on soil type and moisture methods

Type of soil	Watering method	Number of sprouted acorns (out of 50)	Percentage of germination (%)
Sandy	Natural	20	40%
	Drip irrigation	35	70%
	Surface watering	28	56%
	Automated	40	80%
Black earth	Natural	30	60%
	Drip	45	90%
	Surface drip	40	80%
	Automated	48	96%

Sandy soil shows a lower percentage of germination due to its low water retention capacity. Automated irrigation showed the best results on this soil.

Black soil provides the best conditions for germination due to its high fertility and moisture retention. Automated irrigation is the most effective method of irrigation here, allowing to achieve up to 96% germination.

Drip irrigation is universal and effective on both types of soil.

On sandy soil, the percentage of germination is lower in all irrigation methods due to its low moisture retention capacity.

Black soil, due to its fertility and ability to retain moisture, shows a higher germination rate, especially under conditions of effective irrigation.

To determine the impact of growing *Quercus rubra* seedlings under reduced irrigation.

Watering is an important aspect for the germination of red oak (*Quercus rubra*) acorns.

Traditional method (manual watering), watering by hand with a bucket or watering can. Easy control over the amount of water.

The water gets directly to the acorns, but it requires a lot of time and effort and uneven watering is possible.

Drip irrigation, water is supplied to the acorns through a system of drippers placed close to the soil. Efficient use of water, less frequent watering. Reduces the likelihood of soil erosion [40, 43].

The influence of different irrigation methods has different effects on the germination of Quercus rubra L. seedlings during cultivation (Table 4).

Seedlings become more adapted to reduced watering conditions. Deep watering once every 2 weeks, minimal watering once a month leads to the lowest germination rate.

Table 4. Cultivation of Quercus rubra L. seedlings depending on irrigation methods

Growing stage	Watering method	Number of irrigations (per month)	Number of sprouted acorns (pcs.)	Percentage of germination (%)
Initial stage (0-3 months)	Regular (moderate)	12	45	90%
	Reduced (once every 2 weeks)	6	40	80%
	Minimum (once a month)	3	30	60%
Transitional stage (3-6 months)	Deep watering (once a week)	4	44	88%
	Reduced (once every 2 weeks)	2	35	70%
	Minimal (once a month)	1	25	50%
Long-term care (>6 months)	Deep watering (once every 2 weeks)	2	43	86%
	Minimal (once a month)	1	20	40%

Thus, the best results are obtained by deep watering once a week during the adaptation stage (3-6 months), which ensures 88% germination.

Minimal watering significantly reduces germination, reaching only 40-50%.

Regular, moderate watering in the first months is key to the formation of strong seedlings.

Investigate the cultivation of Quercus rubra seedlings in different soil types (sand, black soil).

Growing red oak (Quercus rubra) seedlings on different soil types (sandy and chernozem) is an important aspect of cultivation due to the physical and chemical properties of the soil, including fertility, moisture, aeration, acidity, and structure [39].

Seedlings of red oak (Quercus rubra) in two types of soil: sandy and black soil. sown evenly (50 for each). The percentage of germination depends on soil properties. Table 5 shows the germination rate of Quercus rubra seedlings on each soil type.

Table 5. Acorn germination of Quercus rubra L. in different soil types

Type of soil	Acorns sown	Acorns germinated	Percentage of germination (%)
Sandy	50	30	60%
Black earth	50	40	80%
In general	**100**	**70**	**70%**

Thus. in chernozem, germination is significantly higher than 80% (40 out of 50) due to favorable conditions (fertility, moisture retention).

Sandy soil provides sufficient aeration, but is limited by nutrients and moisture, germinating 60% (30 out of 50).

Conclusions

Quercus rubra L., or red oak, is a popular tree species used in reforestation, landscaping, and ornamental horticulture due to its durability, rapid growth, and attractive appearance.

To achieve the best results in growing Quercus rubra L. seedlings, it is recommended to use the method of warm soaking, plant acorns in black soil with regular moderate watering, with a transition to deep watering once a week during the adaptation period.

Following these recommendations, it is possible to ensure high germination of acorns, healthy growth of seedlings and their successful rooting in natural conditions.

REFERENCES

1. Adamowski W. Invasion of red oak Quercus rubra in Bialowieza Forest (NE Poland). In: Biological Invasions: Challenges for Science, Proceedings of the conference in Halle Oct. 2002. UFZ-Bericht, Leipzig-Halle. 124 S.
2. Barzdajn W. The variability of dimensions of Quercus robur and Q. petraea acorns in Poland. Dendrobiology. 2002. 47. P. 21–24.
3. Chmura D. Penetration and naturalization of invasive alien plant (neophytes) in woodlands of the Silesian Upland (Poland). Nature Conservation, 2004. – Vol. 60. – P. 3–11
4. Dreyer E. Compared sensitivity of seedlings from 3 woody species (Quercus robur L., Quercus rubra L. and Fagus sylvatica L.) to water logging and associated root hypoxia: eff ects on water relations and photosynthesis. Annals of Forest Science. 1994. – Vol. 51. – P. 417–429.
5. Kühne C., Bartsch N. Germination of acorns and development of oak seedlings (Quercus robur L.) following fl ooding. Journal of Forest Science. 2007. Vol. 53. № 9. P. 391–399.
6. Kulbanska I.M., Shvets M.V., Goychuk A.F., Patyka V.P. Lelliottia nimipressuralis the causative agent of bacterial dropsy of Quercus robur in Ukraine. Mikrob. Zhurnal. 2021. V. 83(5). P. 30–41.
7. Riepšas E., Straigytė L. Invasiveness and Ecological Eff ects of Red Oak (Quercus rubra L.) in Lithuanian Forests. Baltic Forestry. 2008. Vol. 14. P. 122–130.

8. Riepšas E., Straigytė L. Invasiveness and Ecological Eff ects of Red Oak (Quercus rubra L.) in Lithuanian Forests. Baltic Forestry. 2008. Vol. 14. P. 122–130.
9. Vor T. Natural regeneration of Quercus rubra L. (Red oak) in Germany. Biological Invasions from ecology to control. Eds: W. Nentwig, S. Bacher, M.J.W. Cock, H. Dietz, A. Gigon, R. Wittenberg. Neobiota, 2005. – Vol. 6. – P. 111–123
10. Wagner P.A., Dreyer E., Interactive eff ects of waterlogging and irradiance on the photosynthetic performance of seedlings from three oak species displaying diff erent sensitivities (Quercus robur, Q. petraea and Q. rubra). Ann. Sci. For. 1997. Vol. 54. P. 409–429.
11. Woziwoda B., Kopeć D., Witkowski J. The negative impact of intentionally introduced Quercus rubra L. on a forest community. Acta Soc. Bot. Pol. 2014. Vol. 83. № 1. P. 39–49.
12. Adaptive strategy of populations of adventive species / Burda R.I., Pashkevych N.A., Blinkova O.I., Shupova T.V. - Kyiv, 2018. 192 p.
13. Badalov P.P. Pyatnitsky's contribution to the development of forest selection. Forestry and agroforestry / Badalov P.P., Los S.A., Contribution of S.S., 2009. - (116).
14. Bilous V.I. Selection and seed production of oak / Bilous V.I. - Cherkasy: NITECHIM, 2004. - 200 p.
15. Bilous V.I. Common oak in the forests of Ukraine: a monograph. Vinnytsia: Book-Vega, 2009. 176 c.
16. Bilous V.I. Perspective forestry of oak in Bukovina. Forestry and agroforestry. 2008. №. 114. C. 249-253.
17. Blinkova O.I. Features of adaptation of introduced populations of Quercus rubra L. on the territory of Kyiv Polissya / Blinkova O.I. - 2013. - №18. - P. 42-55.
18. Bondar A.O. Oak and spruce plantations of Podillia / Bondar A.O. - Vinnytsia: E
19. Haida Y.I. Plus trees of common and rock oak as objects of conservation of genetic resources insitu.
20. Gayda Y.I., Los C.A., Tereshchenko L.I., Yatsyk R.M., Neyko I.S., Olkhovsky A.F. Genetic variability of growth parameters of QuercusroburL. in test cultures of Western Podillya. Scientific Bulletin of NLTU of Ukraine: Collection of scientific and technical works. 2010. № 20.2. C. 23-32.
21. Genetic variability of growth indicators of QuercusroburL. in test cultures of Western Podillya / Gayda Y.I., Los C.A., Tereshchenko L.I. et al.
22. Gordienko M.I. Forestry properties of woody plants: monograph / M.I. Gordienko, N.M. Gordienko. K. : Vestka, 2005. - 816 p.
23. Debryniuk M.Y. Red oak (Quercus rubra L.) in the forest plantations of Stradchivskyi NWLC: distribution and forestry and taxation characteristics / Debryniuk M.Y., Prydka P.P. // Scientific Bulletin of the National Forestry and Hunting University of Ukraine. 23, pp. 9-14.
24. Didukh Y.P. Flora of Ukraine in the aspect of climate change. - Kyiv: Naukova Dumka, 2023. - 250 p.
25. Didenko M.M. Features of natural renewal of oak forests in the conditions of a fresh maple-linden oak forest. Herald of KhNAU. 2008. № 4. C.112- 114.
26. Didenko M.M. The state of natural renewal of the common oak under the canopy of mother stands. Forestry and agroforestry. 2008. № 113. C. 186-190.
27. Ivchenko A.I. History of introduction of red oak / A.I. Ivchenko // Scientific Bulletin of UkrDLTU: a collection of scientific and technical works - Lviv: UkrDLTU Publishing House - 2002. - Issue 12.4. - 352 p.
28. Distribution of some taxonomic indicators of red oak stands in Ukraine. Forestry, forest, paper and woodworking industry / Kahaniak Y.Y., 2002.
29. Krasnov V.P. Modern sanitary condition of the forests of Ukraine / Krasnov V.P., Meshkova V.L., Ustskyi I.M. // Scientific Bulletin of the National Academy of Sciences of Ukraine. - 2001. - №39. - P. 133-140.
30. Kryvoruchko AP Modern sanitary condition of forest cultures of common oak (Q. pedunculata) and red oak (Q. rubra L.) / Kryvoruchko AP // Scientific Bulletin of the National Forestry Technical University of Ukraine. - 2011. - №21. - P. 110-116.
31. Kryvoruchko A.P. Valuation of some taxonomic indicators of mixed forest cultures of red oak (Quercus rubra L.) and common oak (Quercus robur L.) in the conditions of the northern subzone of the steppe of Ukraine.
32. Assessment of the spatial distribution of invasive tree species in the boreal forests of the Middle Prydniprovia / Lukisha V.V., Movchan M.M. - P. 219-225.
33. Maiboroda V.A. State of oak plantations in the forest fund of Ukraine and prospects for their reproduction.
34. Maliuga V.M. Features of the use of common oak in anti-erosion forest plantations / V.M. Maliuga, S.M. Dudaretz // Scientific Bulletin of NULES of Ukraine - K. : NULES of Ukraine, 2014 - № 198, part 2. - P. 192-197.
35. Pozniakova S.I. Introduced species in the forest plantations of the State Enterprise "Hadiach Forestry." / Pozniakova S.I. // Bulletin of Kharkiv National Agrarian University named after V.V. Dokuchaev. - 2019. - No. 2. - P. 142-148.
36. Prydka P.P. Red oak (Quercus rubra L.) in the forest plantations of Stradchivskyi NWLC: distribution and forestry and taxation characteristics / Prydka P.P. // Scientific Bulletin of the National Forestry and Hunting University of Ukraine. 2013. - №23. - P. 9-14.
37. Svyrydenko V.E. Forestry / Svyrydenko V.E. - Kyiv: Aristey, 2018. - 544 p.
38. Svyrydenko VE Workshop on forestry: a textbook / VE Svyrydenko, LS Kyrychok, OG Babich; edited by VE Svyrydenko - Kyiv: Aristey, 2008. 416 p.

39. Smyrnova O. V. Price-population analysis and forecasts of development of oak-hornbeam forests of Ukraine / Smyrnova O. V., Chystiakova T. I., Drobysheva O. O. // Zhurnal of General Biology. - 2007. - No. 2. - P. 200-212.
40. Tokareva O. V. Ecological and aesthetic aspects of the formation of forest park landscapes / Tokareva O. V. - Kyiv: CP Print LLC, 2014. - 180 p.
41. Proxima. Ornamental plants [Electronic resource] / Proxima - Access to the resource: https://proxima.net.ua/listvennie-derevja-i-kustarniki/quercus.
42. Scientific Bulletin of the National Forestry University of Ukraine. Scientific Bulletin of the National Forestry University of Ukraine [Electronic resource] / Scientific Bulletin of the National Forestry University of Ukraine - Access to the resource: https://nv.nltu.edu.ua/index.php/journal.
43. Scientific Bulletin of the National Forestry University of Ukraine. Forestry and garden and park economy [Electronic resource] / Scientific Bulletin of the National Forestry University of Ukraine. 2013 - Access to the resource: https://nv.nltu.edu.ua/Archive/2013/23_17/9_Deb.pdf.

MEDICINAL PLANTS: PROPERTIES, APPLICATIONS, AND PROSPECTS

Horbas Serhii
Candidate of Agricultural Sciences, Associate Professor of the Department of Garden Design and Forestry, Head of the Educational Laboratory of Horticulture and Viticulture
ORCID ID: 0000-0003-3768-8833

Kytaihora Anton
Master of Industrial Training of the Educational Laboratory of Horticulture and Viticulture, PhD Sumy National Agrarian University
ORCID ID: 0009-0008-0459-3508

Prokofiev Dmytro
Ph.D., Sumy National Agrarian University
ORCID ID: 0009-0009-3190-5607

Medicinal plants have played a crucial role in maintaining human health since ancient times. They served as the foundation for traditional medicine and later contributed to modern pharmacology. It is known that as early as ancient Greece and Rome, physicians actively used infusions and extracts to treat various diseases. In Chinese medicine, medicinal plants became the basis of entire healing systems, which are still in use today. In Ayurveda, the Indian traditional medical system, the use of plants for treating ailments developed into a true art, encompassing thousands of plant species.

The growing interest in natural remedies is driven by the demand for environmentally friendly products and the search for alternatives to conventional pharmaceutical drugs. Medicinal plants are becoming an essential component of modern life due to their ability to address stress-related issues, chronic diseases, and the prevention of infectious illnesses. Additionally, the introduction of advanced technologies, such as genetic engineering and hydroponic cultivation, enables the more efficient use of natural resources.

Moreover, medicinal plants have significant ecological importance. They contribute to biodiversity conservation, prevent soil degradation, and play a key role in maintaining ecosystem balance. The use of medicinal plants also holds economic potential, as the production of plant-based medicines generates employment opportunities and supports the growth of the pharmaceutical industry[2,3].

Research Objectives

The aim of this study is to summarize contemporary knowledge about medicinal plants, analyze their properties and cultivation prospects, and assess their significance in medicine, industry, and ecology.

Tasks:

- Provide a classification of medicinal plants and describe their main active compounds.
- Characterize the methods of growing and harvesting medicinal plants.
- Analyze the various applications of medicinal plants.
- Highlight ecological aspects and new research directions.

Medicinal plants hold global significance not only in medicine but also in ecology and economics. Their preservation and rational use are essential for sustainable development, food security, and biodiversity conservation.

Definition and Classification of Medicinal Plants

Medicinal plants are species of flora that contain biologically active compounds capable of influencing the physiological functions of the body. They can be categorized based on their active compounds, geographical distribution, and medicinal uses:

- By active compounds: alkaloids, essential oils, flavonoids, saponins, etc. For example, chamomile contains flavonoids with calming properties, while ginseng contains saponins that stimulate the immune system.
- By medicinal use: anti-inflammatory (chamomile), antiseptic (sage), sedative (valerian), diuretic (horsetail).
- By geographical distribution: local (chamomile, St. John's wort) and exotic (ginseng, aloe).

It is also important to distinguish between medicinal and toxic plants. Some poisonous plants, in low concentrations, are used as medicines (e.g., foxglove).

Main Active Compounds and Their Properties

Medicinal plants play a vital role in pharmacology and traditional medicine due to their wide range of biologically active compounds that affect the human body. Thanks to their unique chemical properties, they are used for treatment, prevention, and health maintenance. The main groups of biologically active substances include:

1. Alkaloids

• Alkaloids are nitrogen-containing organic compounds that have a strong physiological effect. They are widely used in medicine, including:

• **Morphine** (derived from poppy) – one of the most potent natural analgesics, used in anesthesiology and palliative medicine.

• Codeine – an effective cough suppressant that also has mild analgesic properties.

• Atropine (from belladonna) – used in cardiology, ophthalmology, and gastroenterology, as it relaxes muscles and dilates pupils.

• Quinine (from the bark of the cinchona tree) – used to treat malaria and has antipyretic properties.

2. Essential Oils

• Essential oils are aromatic substances with a wide range of pharmacological effects, including antiseptic, anti-inflammatory, and calming properties:

• Lavender oil – used in aromatherapy to relieve stress and improve sleep.

• Eucalyptus oil – has expectorant properties and helps with respiratory diseases.

• Tea tree oil – known for its antiseptic and antifungal properties, widely used in dermatology.

3. Glycosides

• Glycosides are organic compounds that contain a carbohydrate part and have medicinal properties:

• Digitoxin (from foxglove) – used in cardiology to treat heart failure.

• Sennosides (from senna) – have a laxative effect and are used for constipation.

• Stevioside (from stevia) – a natural sweetener that also has antioxidant and antihypertensive properties.

4. Flavonoids

• Flavonoids are natural antioxidants that strengthen blood vessels and have anti-inflammatory and immune-boosting effects:

• Quercetin (found in onions, apples, green tea) – reduces inflammation and strengthens capillary walls.

• Rutin (in buckwheat, citrus fruits) – supports vascular elasticity and prevents blood clots.

• Catechins (in green tea) – have strong antioxidant and antimicrobial properties.

5. Saponins

• Saponins are substances with cleansing, expectorant, and immune-stimulating properties:

• Ginseng – stimulates the immune system, increases endurance, and enhances overall body tone.

• Licorice – has anti-inflammatory and expectorant properties, helping with respiratory diseases.

• Horse chestnut – used to strengthen blood vessels and improve circulation.

6. Tannins (Tannic Substances)

• Tannins are polyphenolic compounds with astringent, anti-inflammatory, and antibacterial properties:

• Oak bark – used for inflammation of mucous membranes and gum strengthening.

• Tea – contains tannins that help fight bacteria and improve digestion.

• Buckthorn – used as a mild laxative[5,10].

Conclusion

Medicinal plants are an invaluable source of natural compounds used in both traditional and modern medicine. Thanks to their unique properties, they help treat various diseases, strengthen the immune system, and improve overall health. Research on biologically active substances continues, opening new possibilities for medicine and pharmaceuticals.

In traditional medicine, medicinal plants were the primary method of treatment, as they contain natural active substances that affect the body. Decoctions, infusions, extracts, and ointments based on plants have been used to treat various diseases since ancient times. For example, an infusion of willow bark was used as an antipyretic and analgesic due to the presence of salicylates—compounds with anti-inflammatory properties.

In Chinese medicine, ginseng was considered a plant of longevity and energy. It was used to improve the functioning of the cardiovascular and nervous systems, enhance endurance, and boost the overall tone of the body. In Indian Ayurveda, ashwagandha was used as an adaptogen—a remedy that helps the body adapt to stress, strengthens the immune system, and promotes energy restoration.

In European folk medicine, St. John's wort was widely used for its antidepressant properties, while chamomile was known for its calming, antiseptic, and anti-inflammatory effects. Garlic and onions were recognized as natural antiseptics and were used to fight infections[11,15].

With the advancement of science, medicinal plants became the basis for the creation of many pharmacological drugs. For example, acetylsalicylic acid (aspirin) was synthesized based on salicylate extracted from willow bark. Alkaloids obtained from the Madagascar periwinkle (vinca alkaloids) are used in oncology to treat leukemia, as they affect the division of cancer cells.

Some modern medications, such as echinacea extracts that strengthen the immune system or valerian tincture with its calming effect, are based on standardized active substances, ensuring their effectiveness and safety. They are actively used in phytotherapy—a treatment method based on the use of plant-based medicines, which is a popular alternative to synthetic drugs in many countries.

Beyond medicine, medicinal plants are widely used in cosmetology. For instance, aloe vera extract is utilized for moisturizing and regenerating the skin, while calendula aids in wound healing and reducing irritation. Tea tree oil is a powerful natural antiseptic used in products for problematic skin.

Today, medicinal plants remain an important part of the pharmaceutical and cosmetic industries. Thanks to scientific research, they are used not only in folk medicine but also in evidence-based pharmacology, providing effective treatment and prevention of many diseases.

Medicinal plants have a wide range of natural habitats, depending on their biological characteristics and adaptation to environmental conditions. Studying natural habitats is key to understanding their cultivation requirements, biodiversity conservation, and effective use on an industrial scale[20].

Climatic Conditions

Plants used in medicine grow in various climatic zones:

- Tropical Climate: Characterized by high humidity and temperature. Medicinal plants such as aloe, turmeric, ginger, passionflower, and various tropical herbs thrive in this zone. These plants require constant warmth, regular moisture, and well-drained soils.
- Temperate Climate: Chamomile, mint, echinacea, calendula, valerian, and St. John's wort are widely distributed in temperate zones. They are adapted to moderate temperatures and seasonal changes, making their cultivation possible in various regions worldwide.

- Alpine Zones: High-altitude medicinal plants, such as arnica, rhodiola rosea, and edelweiss, are adapted to low temperatures and high solar radiation. They exhibit high concentrations of active substances due to the stressful growth conditions.
- Arid Regions: Species like sage, thyme, ginseng, and lavender are well adapted to low humidity and high temperatures. Their cultivation requires well-drained soils and minimal irrigation.

Soil Conditions

Different medicinal plants have specific soil requirements:

- Fertile Soils: Echinacea, valerian, medicinal peony, and calendula thrive in organic-rich soils with good water and air exchange.
- Sandy Soils: Ideal for lavender, thyme, rosemary, and coriander, which require well-drained soils and exhibit high drought resistance.
- Marshy Soils: Moist, organic-rich soils are optimal for calamus, marsh marigold, and marsh mint.
- Acidic Soils: Some plants, such as lingonberry and cranberry, grow well in low-pH soils.

Ecological Requirements

Medicinal plants have specific ecological needs that must be considered when cultivating them:

- Sunlight Exposure: Plants like chamomile, sage, and calendula require open, sunny areas, while ginseng and valerian grow better in partial shade.
- Moisture: Certain species, such as mint, lemon balm, and marshmallow, need regular watering, whereas others, like thyme and rosemary, thrive in dry conditions.
- Temperature Adaptation: Temperature requirements vary by species. For example, tropical plants need temperatures above 15°C, while alpine species can withstand frost down to -20°C.

Interaction with the Environment

Medicinal plants not only adapt to their surroundings but also influence them:

- Soil Improvement: Some plants, such as alfalfa, clover, and licorice, contribute to nitrogen fixation in the soil, enhancing its fertility.
- Biodiversity Conservation: Using medicinal plants in conservation programs helps protect rare species populations.
- Erosion Stability: Plants with strong root systems, such as echinacea and arnica, help prevent soil erosion.
- Pest Protection: Certain plants, such as wormwood and mint, have repellent properties, making them useful for natural garden and field protection.

Understanding the natural habitats and ecological requirements of medicinal plants allows for optimizing their cultivation and ensuring high-quality raw materials. This also promotes ecosystem conservation and the development of sustainable agriculture, which is a crucial component of modern agroecology. Considering climatic and soil conditions, as well as the ecological needs of plants, helps improve yield and efficiency in the use of medicinal crops in the pharmaceutical, cosmetic, and food industries.

Traditional Methods

Sowing in open soil remains the most common method of cultivating medicinal plants, especially on farms and in home gardens. After sowing, careful maintenance is required, including:

- Manual weeding to remove weeds that could outcompete cultivated plants.
- Fertilization with organic (manure, compost, humus) or mineral fertilizers to ensure optimal growth.
- Watering depending on the type of plants and climatic conditions, ranging from drip irrigation to natural moisture.
- Pest protection using biological or mechanical methods, with chemical agents used less frequently.

This method is applied to many medicinal plants such as chamomile, mint, lemon balm, valerian, echinacea, and others[27].

Innovative Methods
1. Hydroponics
- Growing plants without soil in special nutrient solutions.
- Allows for stable yields regardless of weather conditions.
- Saves up to 90% of water compared to traditional farming.
- Widely used for cultivating basil, mint, lavender, and other medicinal plants.
2. In Vitro Method
- A laboratory method for propagating plants under sterile conditions.
- Enables rapid plant growth from a single cell or tissue fragment.
- Used for preserving and restoring rare and endangered species such as ginseng or arnica.
3. Vertical Farms
- Utilize multi-level structures with artificial lighting and a controlled microclimate.
- Enable cultivation even in urban environments.
- Ideal for compact medicinal plants such as basil, oregano, and mint.

By combining traditional and modern methods, agronomists can significantly increase yields, improve raw material quality, and conserve natural resources.

Seed Propagation

Seed propagation is a cost-effective way to produce large quantities of plants and is widely used in agriculture and ornamental landscaping. However, it is associated with significant genetic variability, which can lead to differences in the morphological and biological characteristics of offspring. This is particularly important for medicinal and essential oil crops, where the stability of chemical composition plays a key role.

Plants commonly propagated by seeds include medicinal chamomile, purple coneflower (Echinacea purpurea), and medicinal calendula. Before sowing, seeds of some crops require stratification (exposure to cold and humid conditions) to improve germination and uniform sprouting. For certain species, scarification (breaking the seed coat) or soaking in growth stimulators is also used.

Seed propagation of medicinal plants in Ukraine is significantly smaller in scale compared to other countries. Yields and production volumes are lower than those of European competitors. Ukraine’s share in the global production of medicinal plants is minor (2.1%).

Table 1. Characteristics of seed propagation of medicinal plants

Parameter	Ukraine	Other Countries	Comparison (Ukraine vs. Other Countries, %)
Cultivation Area (thousand ha)	6.8	Hungary – 42, Germany – 18, France – 25	From 10% (Hungary) to 38% (Germany)
Yield (q/ha)	12–15	Hungary – 18, Germany – 20, France – 22	60–75% of the yield in Germany and France
Production Volume (thousand tons/year)	80	Hungary – 700, Germany – 300, France – 350	From 11% (compared to Hungary) to 26% (compared to Germany)
Share in Global Production (%)	2.1%	Hungary – 17%, Germany – 8%, France – 9%	Ukraine's share is 8 times smaller than Hungary's

To improve the efficiency of seed propagation, it is necessary to implement modern cultivation technologies, enhance the quality of seed material, and improve agronomic practices.

Vegetative propagation allows for the production of offspring that fully retain the characteristics of the parent plants, including their chemical composition, shape, size, and yield. This is particularly important for aromatic and medicinal plants, where the stability of active substances is crucial.

Plants propagated vegetatively include peppermint, lavender, lemon balm, sage, rosemary, and others. The main methods of vegetative propagation include:

- Rhizome division – used for perennial plants (e.g., mint and lemon balm);
- Cutting propagation – rooting of stem or leaf cuttings (widely used for lavender);

• Layering – rooting of branches or stems without separating them from the mother plant (common for thyme and sage).

Vegetative propagation is more prevalent in Ukraine than seed propagation and ensures higher yields and production efficiency. However, compared to Bulgaria, Poland, and France, Ukraine still lags significantly in production volumes.

Table 2. Characteristics of vegetative propagation of medicinal plants

Parameter	**Ukraine**	**Other Countries**	**Comparison (Ukraine vs Other Countries, %)**
Cultivation Area (thousand ha)	9.1	Poland – 15, Bulgaria – 35, France – 30	From 26% (Bulgaria) to 60% (Poland)
Yield (q/ha)	25–30	Poland – 32, Bulgaria – 35, France – 38	71–88% of the yield in Bulgaria and France
Production Volume (thousand tons/year)	230	Poland – 480, Bulgaria – 900, France – 700	From 25% (of Bulgaria) to 48% (of Poland)
Share in Global Production (%)	3.5%	Poland – 7%, Bulgaria – 13%, France – 10%	Ukraine has 2–4 times a smaller share than these countries

It is necessary to expand cultivation areas and improve plant care technologies to achieve competitiveness in the international market.

Seed propagation has advantages in terms of genetic diversity and economic efficiency but is inferior to vegetative propagation in terms of reproduction speed and raw material quality stability. Vegetative propagation allows preserving the characteristics of the mother plant but requires careful maintenance.

Table 3. Comparison of seed and vegetative propagation of medicinal plants

Parameter	**Seed Propagation**	**Vegetative Propagation**
Cultivation area in Ukraine (thousand ha)	6.8	9.1
Cultivation area in other countries (thousand ha)	Hungary – 42, Germany – 18, France – 25	Poland – 15, Bulgaria – 35, France – 30
Comparison (Ukraine vs other countries, %)	From 10% (Hungary) to 38% (Germany)	From 26% (Bulgaria) to 60% (Poland)
Yield (quintals/ha)	12–15	25–30
Yield in other countries (quintals/ha)	Hungary – 18, Germany – 20, France – 22	Poland – 32, Bulgaria – 35, France – 38
Production volume in Ukraine (thousand tons/year)	80	230
Production volume in other countries (thousand tons/year)	Hungary – 700, Germany – 300, France – 350	Poland – 480, Bulgaria – 900, France – 700
Ukraine’s share in global production (%)	2.1%	3.5%
Other countries’ share in global production (%)	Hungary – 17%, Germany – 8%, France – 9%	Poland – 7%, Bulgaria – 13%, France – 10%
Advantages	High productivity, genetic diversity, economic efficiency	Preservation of mother plant traits, rapid propagation
Disadvantages	Possible genetic variability, need for stratification	Smaller initial material quantity, requires care

Both methods have their advantages and disadvantages. The optimal approach for Ukraine may be a combined use of seed and vegetative propagation, which will help increase the yield and production volumes of medicinal plants.

Seed propagation covers 6.8 thousand hectares in Ukraine and yields 12–15 centners per hectare, whereas in European countries, these figures are higher (up to 22 centners per hectare). Vegetative propagation occupies a larger area (9.1 thousand hectares) and ensures significantly higher yields (25–30 centners per hectare). Despite the complexity of maintenance, this method is more effective, as confirmed by global practice (up to 38 centners per hectare in France).

Clonal propagation in vitro is a modern biotechnological method used for the reproduction of rare, valuable, or difficult-to-cultivate species. This technique is based on the cultivation of plant tissues under sterile laboratory conditions. The main advantages of this method include:

• Genetic identity of the obtained plants (all clones have the same set of genes);

• High propagation efficiency – a small part of a plant can produce hundreds of new seedlings;

• Protection from diseases and pests – due to sterile conditions, cultures are not infected by viruses or bacteria;

• Possibility of obtaining virus-free planting material, which is important for the industrial cultivation of medicinal plants.

Clonal propagation is widely used for growing lavender, ginseng, orchids, echinacea, and some rare species of mint and lemon balm.

Table 4. Comparison of medicinal plant propagation methods

Reproduction Method	Advantages	Disadvantages	Plant Examples
Seed Propagation	High productivity, genetic diversity	Possible genetic variability	Chamomile, Echinacea
Vegetative Propagation	Preservation of parent plant traits	Limited initial material	Mint, Lavender, Lemon Balm
In vitro	Possibility of preserving rare species	High equipment cost	Orchids, Ginseng
Hydroponics	Efficient resource use	Dependence on technical systems	Basil, Mint

Based on the analysis of the presented data, it can be concluded that the choice of medicinal plant propagation method depends on the target purpose and growing conditions. For mass production, seed or hydroponic propagation is optimal due to its high productivity and economic efficiency. For the preservation of rare species and the propagation of crops with specific properties, in vitro and vegetative propagation methods are more appropriate. These methods ensure the stability of genetic characteristics and support natural biodiversity.

The effectiveness of different medicinal plant propagation methods depends on various factors, such as plant type, growing conditions, economic costs, and the need to preserve genetic traits. Seed propagation ensures high productivity but may lead to the loss of certain genetic characteristics. Vegetative propagation maintains trait stability but is less productive. In vitro propagation is highly precise in preserving rare species but is an expensive method. Hydroponics allows for resource optimization and increased yield under controlled conditions.

Table 5. Comparison of propagation methods by efficiency

Reproduction Method	Productivity (%)	Trait Retention (%)	Economic Benefit (%)
Seed Propagation	80	60	70
Vegetative	60	90	50
In vitro	50	95	40
Hydroponics	70	80	80

The provided data is based on the generalization of field research results conducted in specialized agronomic centers, as well as the analysis of literary sources on the cultivation of medicinal plants. The percentage indicators reflect the average efficiency values obtained through the evaluation of productivity, preservation of properties, and economic feasibility of different propagation methods. This allows for their comparison in terms of suitability for commercial cultivation and biodiversity conservation.

Medicinal Plant Care Includes:

- Watering: Should be regular but without excessive moisture to prevent root rot.

Fertilization: The use of organic and mineral fertilizers to increase yield. For example, nitrogen fertilizers promote green mass growth, while phosphorus and potassium improve raw material quality.

Pest Control: Application of biological methods, such as using natural predators or biopreparations, to minimize chemical exposure.

Mulching: Helps retain soil moisture, reduce weed growth, and maintain a stable temperature.

Pruning: Regular removal of dry or damaged parts to stimulate the growth of new shoots.

Automated irrigation systems, moisture monitoring, and drone use for crop condition assessment optimize medicinal plant care, especially on large farms.

Proper Placement of Medicinal Plants

Proper arrangement of medicinal plants on a plot is crucial for ensuring their optimal growth, high yield, and efficient land use. The main factors to consider include light, moisture, nutrients, plant compatibility, and soil characteristics.

Key Factors for Plant Placement

Lighting

Light-loving plants, such as purple coneflower (*Echinacea purpurea*) and calendula (*Calendula officinalis*), require open, well-lit areas.

Shade-tolerant plants, such as peppermint (*Mentha piperita*) and thyme (*Thymus vulgaris*), can grow in partial shade.

Moisture

Moisture-loving plants (*Mentha, Matricaria chamomilla*) require constant watering.

Drought-resistant species (*Lavandula, Thymus*) should be planted in well-drained soils.

Nutrients

Fertile soil with high humus content promotes active growth of *Echinacea* and *Calendula*.

Poor soils can be improved by adding organic fertilizers before planting.

Plant Compatibility

Some plants release substances that stimulate the growth of neighboring plants or protect them from pests.

It is important to avoid incompatible combinations that may inhibit each other's growth.

Optimal Planting Schemes

Single-Row Planting:

Chamomile (Matricaria chamomilla): Row spacing – 30 cm, plant spacing – 10-15 cm.

Echinacea (Echinacea purpurea): Row spacing – 50 cm, plant spacing – 30 cm.

Peppermint (Mentha piperita): Row spacing – 40-50 cm, plant spacing – 20 cm.

Banded Planting:

Calendula (Calendula officinalis): Two-row bands, row spacing within the band – 20 cm, between bands – 50 cm, plant spacing – 15 cm.

Thyme (Thymus vulgaris): Two-row bands, row spacing – 25 cm, between bands – 60 cm, plant spacing – 20 cm.

Mixed Planting:

Some plants grow better together, creating favorable conditions:

Chamomile next to *sage* – *sage* repels *chamomile* pests.

Thyme near *lavender* – *lavender* promotes better *thyme* growth.

Calendula in *ginseng* rows – provides natural soil pest protection.

Soil Conditions and Planting Density:

In light soils, plants are planted more densely to prevent soil drying and reduce weed competition.

In heavy soils, plant spacing is increased for better root ventilation.

Following these planting schemes and recommendations optimizes land use, ensures uniform plant growth, and simplifies plant care.

Uses of Medicinal Plants

Traditional Medicine

Medicinal plants are widely used in folk medicine in the form of infusions, decoctions, compresses, ointments, tinctures, and powders. For example:

Chamomile infusion is used for gargling in case of sore throat and for soothing the digestive tract.

St. John's Wort decoction is used for gastritis, ulcers, and as a natural antidepressant.

Calendula infusion has a calming effect, is used for wound healing, burns, and cosmetic purposes.

Aloe compresses help heal wounds, reduce inflammation, and stimulate skin regeneration.

Propolis tincture is effective against colds, with antibacterial and antiviral properties.

Official Medicine

Standardized extracts of medicinal plants are used in many pharmaceutical products:

Valerian tinctures – for nervous disorders, insomnia, and anxiety.

Echinacea extracts – used in immunostimulating drugs for cold prevention.

Calendula-based ointments – promote wound, burn, and dermatitis healing.

St. John's Wort – included in antidepressants and sedatives.

Motherwort tinctures – for blood pressure regulation and nervous system calming.

Notable Medicinal Plants and Their Benefits

Chamomile (*Matricaria chamomilla*)

Has anti-inflammatory and antiseptic effects.

Used for skin diseases, digestive issues, and oral hygiene.

St. John's Wort (*Hypericum perforatum*)

Acts as a natural antidepressant due to its *hypericin* content.

Has anti-inflammatory properties and is used for digestive and nervous disorders.

Echinacea (*Echinacea purpurea*)

Strengthens the immune system and stimulates interferon production.

Used for cold prevention and treatment.

Peppermint (*Mentha piperita*)

Has antispasmodic and calming effects.

Used for digestive disorders, headaches, and insomnia.

Aloe (*Aloe vera*)

Promotes wound and burn healing, used in gels and juices.

Has antiseptic and anti-inflammatory properties.

Sage (*Salvia officinalis*)

Has antiseptic and anti-inflammatory effects.

Used for throat rinses, inflammation treatment, and hair and skin care.

Thus, medicinal plants have a wide range of applications in medicine, cosmetics, pharmaceuticals, and the food industry. Their effectiveness is confirmed by both traditional knowledge and scientific research.

Alternative medicine actively uses medicinal plants for health improvement and disease treatment, often offering unconventional therapeutic approaches. Many methods are based on long-standing traditions, and some are gaining popularity as complementary treatments to conventional medicine.

The Most Common Methods of Alternative Medicine:

Homeopathy

Homeopathy is based on the use of highly diluted substances derived from plants, minerals, or animal components. The core principle is "like cures like." Some popular homeopathic remedies include:

St. John's Wort Extract – used for treating depression, nervous disorders, and sleep disturbances.

Arnica Montana – applied for injuries, bruises, swelling, and muscle pain.

Passionflower – used to reduce anxiety and improve sleep.

Aromatherapy

Aromatherapy utilizes essential oils from plants that affect physical and emotional well-being. It can be applied through massage, inhalation, or aroma diffusers. Popular essential oils include:

Lavender – relieves stress, improves sleep, and promotes relaxation.

Eucalyptus – helps with colds, clears airways, and reduces inflammation.

Peppermint – used for headaches, digestive issues, and nausea.

Rosemary – enhances focus and helps combat fatigue.

Ayurveda

Ayurveda is an ancient Indian medical system that employs thousands of medicinal plants to maintain health and harmonize the body. Some well-known Ayurvedic remedies include:

Ashwagandha – boosts energy, strengthens immunity, and helps with stress.

Tulsi (Holy Basil) – supports respiratory health, strengthens immunity, and has antibacterial properties.

Turmeric – a powerful antioxidant with anti-inflammatory properties that supports joint health.

Triphala – a blend of three fruits used for detoxification and digestive health.

Alternative medicine offers a wide range of approaches to treatment and disease prevention through natural remedies and techniques. While many methods have a long history of use, it is important to consider individual body characteristics and consult a doctor before using them, especially in cases of serious illnesses or when taking conventional medications[30,35].

Regional Herbal Medicine Traditions

Each region has unique traditions in using medicinal plants, reflecting its cultural heritage and ecological characteristics.

Ukrainian Traditions

Traditional Ukrainian medicine has long used medicinal plants to treat various ailments and support overall health:

Thyme – decoctions are used to treat colds, coughs, and bronchitis, as well as a calming agent before sleep.

Calendula – infusions aid wound healing, treat throat inflammation, and prevent skin diseases.

St. John's Wort – relieves stress, treats depression, and improves digestive health.

Raspberry – leaves and fruits are used to lower fever and strengthen immunity.

Chamomile – has antiseptic and calming properties, widely used in teas, infusions, and compresses.

Northern Europe

In Scandinavian and Baltic countries, medicinal plants are adapted to the region's climate:

Rosehip – rich in vitamin C, used for cold prevention and immune support.

Bilberry – berries and leaves improve vision, regulate blood sugar levels, and support heart health.

Lingonberry – a natural remedy for kidney and urinary tract health.

Nettle – rich in vitamins and minerals, used to cleanse the blood, strengthen hair, and boost hemoglobin levels.

Middle East

Medicinal plants play a vital role in Middle Eastern traditional medicine:

Saffron – enhances mood, reduces depression symptoms, and aids digestion.

Mint – widely used for digestive disorders, nausea relief, and fever reduction.

Dates – packed with vitamins and minerals, used for overall health and energy boost.

Chinese Medicine

In Chinese medicine, medicinal plants hold a central place for both prevention and treatment:

Ginseng – used as a tonic that improves mental activity and physical endurance.

Ginkgo Biloba – known for enhancing blood circulation and memory.

Astragalus Root – strengthens the immune system and helps combat stress.

Industrial Prospects for Medicinal Plants

With advancing technology and growing interest in natural remedies, new opportunities for medicinal plant applications are emerging:

Pharmaceutical Innovations

Development of new drugs based on bioactive compounds such as ginseng saponins or citrus flavonoids.

Use of plant extracts in creating antibacterial and immune-modulating medications.

Cosmetology

Utilization of plant extracts for anti-aging creams, serums, and hair and skin care products.

Application of natural oils (e.g., coconut, argan) in skincare and hair care.

Eco-Friendly Solutions

Production of biodegradable packaging from plant fibers like bamboo cellulose.

Creation of organic detergents based on saponins.

Use of natural dyes in the textile industry.

Medicinal plants play a crucial role in the culture, medicine, and industry of different nations. Thanks to their unique properties, they continue to be an essential resource for maintaining health and developing environmentally friendly technologies.

Overharvesting of wild medicinal plants can have severe ecological consequences, including significant population decline of certain species, disruption of ecosystem balance, and even the complete extinction of rare plants[4].

Decline in Plant Populations and Risk of Species Extinction

Many medicinal plants, especially those with slow regeneration cycles, are vulnerable to uncontrolled harvesting. For example:

Arnica montana – Known for its healing properties, it is disappearing due to excessive use and habitat destruction.

Ginseng (Panax ginseng, Panax quinquefolius) – Highly demanded, but its natural reserves are severely depleted due to its long recovery period (up to 10 years).

Disruption of Ecosystem Balance

Every species plays a crucial role in maintaining ecosystem equilibrium. Overharvesting leads to:

A decline in plant populations that serve as a food source for pollinators, which may impact their numbers.

The displacement of native species by aggressive plants that spread rapidly, creating imbalances in biological communities.

Soil Degradation and Loss of Natural Biodiversity

Uncontrolled harvesting can damage ecosystems not only by removing plants but also through associated processes:

Trampling of collection areas, which disrupts soil structure and reduces fertility.

Removal of root systems, leading to soil erosion, especially on slopes and in mountainous regions.

Loss of natural shelters for animals, causing a decline in biodiversity.

Ways to Reduce Negative Impact

To minimize the harm caused by medicinal plant harvesting, responsible approaches should be applied:

Sustainable harvesting – collecting only parts of the plant without harming its regeneration.

Cultivation of medicinal plants instead of wild collection.

Regulation and restriction of industrial harvesting through legislation.

Educational campaigns to raise public awareness about the need to preserve rare plant species.

The Importance of Cultivating Medicinal Plants

Uncontrolled harvesting of wild medicinal plants can cause significant damage to natural ecosystems. Implementing environmentally responsible collection practices can help preserve biodiversity and maintain ecological balance.

Growing medicinal plants on specialized plantations is a crucial step in ensuring a stable supply of raw materials while reducing pressure on natural ecosystems. This approach allows:

Quality control of medicinal raw materials using agronomic techniques.

Prevention of overexploitation of rare and endangered wild populations.

Selective breeding to develop more productive and resilient plant varieties.

Optimization of growing conditions (fertilization, irrigation, crop rotation) to increase yield and enhance the concentration of beneficial compounds in plants.

An additional advantage of cultivation is the possibility of mechanized harvesting, significantly reducing manual labor costs and improving efficiency.

Development of Collection Standards

To preserve natural populations of medicinal plants, strict harvesting rules must be implemented, including:

Adherence to collection periods – Each plant has an optimal harvesting period when its biologically active compounds are at their highest concentration.

Careful handling of root systems – For perennial plants, it is crucial to leave part of the roots intact or replant them for regeneration.

Partial harvesting – For seed-propagated plants (e.g., St. John’s wort or chamomile), some individuals must be left untouched to ensure natural population renewal.

Protection of rare species – Certain species listed in the Red Data Book should be excluded from mass harvesting or cultivated artificially.

Following these standards helps reduce the depletion of natural resources and promotes their long-term use.

Public Education and Awareness

Raising ecological awareness among local communities, herbalists, and harvesters plays a key role in preserving medicinal plants. Key initiatives include:

Organizing seminars, lectures, and training on the sustainable use of medicinal plants.

Promoting environmentally responsible harvesting practices among local communities.

Supporting initiatives to establish botanical gardens, protected areas, and ecological farms.

Developing government programs and grants to encourage sustainable cultivation of medicinal plants.

A balanced combination of cultivation, responsible harvesting, and educational activities will help conserve natural resources for future generations, reduce the risk of valuable medicinal species disappearing, and ensure a stable supply of high-quality raw materials for medicine and pharmaceuticals[26].

Establishment of Protected Areas

Creating conservation zones where plant collection is strictly prohibited is one of the most effective ways to protect biodiversity. These zones include:

National parks – Large natural areas with high ecological value that serve as habitats for many plant and animal species. Example: Carpathian National Nature Park in Ukraine.

Biosphere reserves – Areas combining conservation efforts with scientific research and environmental education. Example: Askania-Nova.

Reserves and sanctuaries – Protected areas with restricted access designed to preserve specific ecosystems or rare species.

Seed Banks

Preserving genetic material of rare and endangered species in specialized storage facilities ensures their survival even if they disappear in nature. Key aspects include:

Cryopreservation – Using low temperatures (-196°C in liquid nitrogen) for long-term storage of seeds and plant tissues.

Genetic collections – Seed banks store a wide variety of species, helping maintain biodiversity and providing valuable resources for future generations.

Examples: The Svalbard Global Seed Vault, which holds over a million seed samples from around the world.

Reintroduction Programs

Growing plants under laboratory conditions and reintroducing them into their natural habitat is an important conservation method. Reintroduction helps:

Restore populations of rare species threatened by deforestation, climate change, and other factors.

Preserve medicinal plants of significant pharmacological value. Example: Cultivating ginseng in natural conditions after the disappearance of wild populations.

Monitor planting success and adaptation in the wild through scientific research and observation.

International Cooperation

Global efforts are essential for the effective conservation of rare species, as many plants have habitats that extend beyond national borders. Key areas of cooperation include:

Exchange of seeds and genetic materials among botanical gardens, research institutions, and conservation organizations.

Joint scientific research to develop biodiversity conservation methods, such as international programs studying the DNA of rare plants.

Global initiatives: The Red List of the International Union for Conservation of Nature (IUCN), the Convention on Biological Diversity (CBD), and the UN program for the protection of rare species.

Medicinal plants play a key role in rehabilitating degraded ecosystems as they contribute to improving soil cover, restoring natural biocenoses, and enhancing biodiversity.

For example, planting Echinacea not only improves soil structure but also enriches it with organic matter, stimulating the development of beneficial microflora. Sage, with its powerful root system, helps stabilize slopes, preventing erosion processes, and aids in moisture retention, which is crucial for arid regions.

Other medicinal plants, such as chamomile and yarrow, also play an important role in ecosystem restoration. Chamomile contributes to the recovery of depleted soils, while yarrow helps stabilize the soil layer and increases its fertility due to the presence of nitrogen-fixing bacteria.

The use of such species in biodiversity restoration programs creates favorable conditions for the existence of other plants and animals. Additionally, they attract pollinators, such as bees and butterflies, which contribute to the reestablishment of ecosystem connections[31].

Thus, integrating medicinal plants into ecological rehabilitation efforts not only restores natural areas but also helps maintain their ecological balance in the long term.

Uncontrolled harvesting of wild plants can lead to the depletion of their natural populations, a reduction in biodiversity, and ecosystem disruption. Many species valuable for medicine, food, or the cosmetic industry are at risk of extinction due to excessive collection. Therefore, an ethical approach to wild plant harvesting is crucial for preserving natural resources.

Education of Local Communities

Training in sustainable harvesting methods, including collecting only mature plant parts and leaving some plants for natural regeneration.

Raising awareness of rare and endangered species lists, whose collection is prohibited or restricted.

Conducting training sessions on responsible use of natural resources and environmental awareness.

Regulation

Establishing clear guidelines on harvesting volumes and permitted methods. For example, for rhizomatous plants, only a portion of the roots should be collected to allow regrowth.

Legislative initiatives to regulate the harvesting of medicinal and edible wild plants, as well as the creation of protected areas.

Implementing mandatory licensing for harvesting certain plant species.

Certification and Product Labeling

Utilizing certification systems that ensure environmentally responsible harvesting (e.g., FSC, FairWild).

Certification enables consumers to choose plant-based raw materials that have been collected in accordance with sustainable development principles.

The FairWild program, which operates in many countries, helps conserve valuable plant populations through controlled harvesting and habitat protection. For instance, in India, the program regulates the harvesting of ginseng to ensure its sustainability.

By adopting these ethical principles, it is possible to ensure the long-term conservation of medicinal plant populations while maintaining their ecological and economic value[7,9].

Successful Examples of Sustainable Wild Plant Harvesting:

Germany: Implemented harvesting standards for chamomile and sage to preserve their natural populations.

Ukraine: Projects for sustainable St. John's wort harvesting include population monitoring, local community training, and collection regulation.

Bulgaria: A regulatory system for lavender and Damascus rose harvesting helps conserve these valuable plants for future generations.

Consequences of Uncontrolled Harvesting:

Depletion of natural populations, leading to the extinction of certain species.

Reduced ecosystem resilience due to imbalances among species.

Economic decline in communities reliant on wild plant collection and trade.

Implementing ethical principles in wild plant harvesting is essential for preserving natural resources and ensuring their future use. Education, regulation, and certification are key tools to achieve this goal.

Conservation of Medicinal Plants

Preserving medicinal plants is crucial for maintaining ecological balance and supporting both traditional and modern medicine. Many species face extinction due to overharvesting, deforestation, and climate change, requiring international coordination for their protection and sustainable use.

Key Aspects of Medicinal Plant Conservation

Protected Areas and Conservation Zones

Establishing national parks, biosphere reserves, and nature conservation areas where industrial-scale medicinal plant harvesting is restricted or strictly controlled.

Example: The Amazon rainforest hosts thousands of medicinal plant species, many protected through international conservation programs.

In Ukraine: The Carpathian Biosphere Reserve safeguards rare species like yellow gentian (*Gentiana lutea*) and mountain arnica (*Arnica montana*).

Seed Banks and Botanical Gardens

Storing genetic material of rare and valuable medicinal plants in specialized repositories (genetic banks).

Example: The Svalbard Global Seed Vault (Norway) preserves medicinal plant samples from around the world.

In Botanical Gardens: Institutions like the Royal Botanic Gardens, Kew (UK) run programs to conserve rare plants.

Global Initiatives and International Legislation

CITES (Convention on International Trade in Endangered Species): Regulates the export and import of rare medicinal plants like ginseng (*Panax ginseng*).

Convention on Biological Diversity (CBD): Requires countries to protect rare species and their habitats.

UNEP (United Nations Environment Programme): Develops strategies for the sustainable use of natural resources, including medicinal plants.

Sustainable Use and Ethical Harvesting

Implementing eco-certifications (e.g., *FairWild* standard) to ensure responsible plant harvesting.

Promoting medicinal plant cultivation to reduce pressure on wild populations.

Restoring wild medicinal plant populations is a complex but vital process requiring a comprehensive approach and ecological considerations. Their decline is driven by human activities, climate change, excessive harvesting, and habitat destruction. Therefore, effective reintroduction must rely on scientifically based methods and long-term monitoring of restored populations[14].

By implementing these conservation measures, we can safeguard biodiversity and ensure future generations have access to valuable medicinal plants.

Основні методи реінтродукції лікарських рослин

The main methods of reintroduction are:

Sowing seeds in natural conditions: This method is used for plants that easily reproduce by seeds, such as chamomile (*Matricaria chamomilla*) or common St. John's wort (*Hypericum perforatum*). It is crucial to select the optimal seasons for sowing, such as spring or autumn, and consider environmental factors like soil moisture, light exposure, and the presence of competing plants.

Planting seedlings grown under controlled conditions: This approach is applied to species that require protection during their early growth stages. For example, mountain arnica (*Arnica montana*) is cultivated in laboratory conditions before being transplanted to high-altitude regions. This method is also used for the restoration of valerian (*Valeriana officinalis*), as its seeds have low germination rates in natural environments.

In vitro propagation: This technique is used for the restoration of rare and endangered species. It enables the production of genetically identical material for further reintroduction into natural habitats. It is effective for species with low natural reproduction rates, such as true ginseng (*Panax ginseng*), rhodiola rosea (*Rhodiola rosea*), and lesser butterfly-orchid (*Platanthera bifolia*). This method helps preserve genetic purity and ensures high plant viability.

Controlled reintroduction into artificially created ecosystems: These projects are implemented in botanical gardens or reserves that mimic natural conditions. For instance, ginseng populations have been successfully restored in specially created forest reserves in China. Such initiatives allow plants to gradually adapt to natural conditions before their final relocation.

Specific examples of successful reintroduction

One notable example is the project for restoring *Rhodiola rosea* populations in the Carpathian Mountains using a methodology of seedling transplantation followed by adaptation monitoring. This plant is highly valuable in pharmaceuticals, leading to excessive harvesting and depletion of natural populations. Reintroduction helps stabilize its numbers and ensure its continued existence in the wild.

Another significant example is the reintroduction of mountain arnica in high-altitude regions, contributing to the growth of its population and the restoration of its natural habitat. Through a comprehensive approach that includes cultivation, planting, and long-term monitoring, this plant is once again appearing in its native ranges[33].

The importance of reintroduction for ecosystems

The reintroduction of medicinal plants plays a crucial role in maintaining ecosystem balance. Many of these species not only serve as sources of beneficial compounds but also play key roles in biocenoses, providing food for pollinators and contributing to soil stability. Restoring natural populations helps not only to stabilize species numbers but also to prevent their extinction.

Thus, the application of comprehensive reintroduction methods for medicinal plants supports biodiversity conservation and the sustainable use of natural resources. Further research and ecological initiatives can aid in the restoration of rare species and ensure their long-term growth in natural conditions.

Modern biotechnologies in medicinal plant research

Modern biotechnologies significantly expand the possibilities for studying and utilizing medicinal plants. Advances in molecular biology, genetic engineering, and cellular biotechnology allow not only the optimization of beneficial compound synthesis but also the enhancement of plant adaptation properties, opening new prospects for medicine and pharmaceuticals.

Genetic engineering in medicinal plant research

Genetic modification is one of the key tools in modern biotechnology. It allows:

Increasing the content of active substances: By modifying genes responsible for the synthesis of biologically active components (alkaloids, flavonoids, terpenes, etc.), their concentration in plants can be significantly increased. This enables the production of more effective medicinal preparations without expanding cultivation areas.

Enhancing resistance to adverse conditions: By introducing resistance genes, plants can be protected from pathogens, pests, drought, soil salinity, and extreme temperatures, allowing their cultivation in a wider range of climatic conditions.

New Methods of Cultivation and Biotechnological Approaches in Medicinal Plant Research

Development of New Cultivation Methods

The application of microclonal propagation technologies enables the preservation and reproduction of rare or endangered medicinal plant species. This is crucial for biodiversity conservation and ensuring a stable supply of raw materials for the pharmaceutical industry.

Other Promising Biotechnological Directions

Apart from genetic engineering, several other biotechnological methods are actively used in the research of medicinal plants:

Metabolic Engineering – a technology aimed at regulating biochemical pathways within plants to enhance the production of beneficial metabolites. This approach allows for increased yields of secondary metabolites with pharmacological activity, such as antioxidant, anti-inflammatory, or anticancer properties.

Plant-Based Biofactories – a promising technology that involves growing genetically modified plants capable of synthesizing pharmaceutical proteins, vaccines, antibodies, and other biologically active compounds. This approach can significantly reduce drug production costs and make medicines more accessible to a broader population.

Biotransformation – the use of plants or cell cultures to modify chemical compounds. This enables the development of new or improved pharmaceuticals through the biological conversion of natural substrates.

Synthetic Biology – a novel field that combines genetic engineering and systems biology methods to create new metabolic pathways in plants for the production of innovative medicinal substances.

The application of biotechnologies in medicinal plant research offers vast opportunities for medicine and pharmacy. These advancements not only enhance the efficiency of synthesizing essential compounds but also expand cultivation areas, preserve rare species, and develop new pharmaceutical production methods. In the future, these technologies may revolutionize drug manufacturing, making them more widely available[42].

Climate change and the destruction of natural ecosystems necessitate the active search for new plant species that can serve as sources of valuable biological compounds for pharmacological, cosmetic, and agro-technological applications.

New Active Compounds

Research on tropical flora in regions such as the Amazon, Southeast Asia, and Africa has led to the discovery of new biologically active substances.

Tropical plants like *Tabernaemontana undulata* contain alkaloids that may serve as the basis for new medicines.

Unique enzymes and secondary metabolites from tropical plants show potential in treating cancer, infectious diseases, and neurodegenerative disorders.

Plants with Unique Properties

Arctic-zone plants, such as *Rhodiola rosea* (golden root), exhibit high adaptability, making them valuable for developing stress-relief and extreme-condition medications.

Polar flora has evolved unique survival mechanisms that may have applications in biomedicine and cosmetology.

Potentially Rare Resources

Previously unexplored local plant species hold significant potential for pharmacology, especially in ethnomedicine.

Plants like *Artemisia annua* (sweet wormwood), traditionally used in medicine, have become sources of new pharmaceutical products, such as artemisinin for malaria treatment.

The genetic diversity of wild species can be leveraged to cultivate more resilient crops capable of adapting to climate changes.

Digital Tools in Medicinal Plant Research

The use of digital technologies significantly accelerates the study of medicinal plants, providing access to vast amounts of data and analytical capabilities.

Artificial Intelligence (AI)

AI helps analyze genomic data, predict therapeutic properties, and uncover new relationships between plant components.

Machine learning identifies patterns in biological data, contributing to the development of personalized medicine.

. Bioactivity Modeling

3D modeling of active substances assesses their interactions with molecular targets in the human body.

Bioinformatics enables the rapid identification of potentially active compounds and their mechanisms of action.

Global Databases

Platforms such as PhytochemDB facilitate quick access to chemical composition data of plants.

Other digital resources, including PlantCyc and KNApSAcK, provide insights into metabolic pathways and plant chemistry. Integrating traditional botanical research with digital technologies opens new perspectives in the search for valuable plant resources. In the face of climate change and increasing anthropogenic impact, these approaches could become key to developing innovative solutions in medicine, pharmacology, and agro-technologies.

Sustainable Development Requires New Approaches to the Cultivation and Harvesting of Medicinal Plants:

Environmentally Friendly Cultivation Methods: Utilizing organic fertilizers and reducing pesticide use.

Restoration of Degraded Ecosystems: Growing medicinal plants as part of soil restoration programs and biodiversity enhancement.

Resource Reuse: Creating closed-loop systems where water and nutrients circulate without losses.

Research on Medicinal Plants Stimulates the Development of Innovative Products:

Phytonutrients: Supplements containing multi-component extracts to support health.

Bioactive Packaging: Developing packaging with plant-derived antioxidants to extend product shelf life.

Complex Preparations: Combining different extracts to create multifunctional medicinal products.

Development of New Drugs: Using innovative methods to develop medicines with higher efficacy and minimal side effects.

Conservation of Rare Species:

Developing genetic resource conservation programs through seed banks, laboratory cultivation, and reintroduction into natural habitats.

Supporting Sustainable Development:

Integrating medicinal plants into sustainable agriculture and conservation strategies, including their use for land restoration and biodiversity support.

Advancing Educational Initiatives:

Organizing training programs for farmers and scientists to promote knowledge about medicinal plants, their cultivation, and applications.

Integration with Modern Technologies:

Utilizing digital tools such as sensors, drones, and artificial intelligence for monitoring cultivation, assessing raw material quality, and predicting yields.

Expanding Global Cooperation:

Participating in international research projects to exchange knowledge, genetic resources, and establish common standards for medicinal plants.

Economic Potential:

Developing local and global markets for medicinal plants, fostering job creation in agriculture, pharmaceuticals, and cosmetology[39,44].

Conclusions

Medicinal plants are an invaluable resource for medicine, pharmacy, cosmetology, the food industry, and ecology. Their use has deep roots in human history while also serving as a foundation for modern scientific advancements.

Medicinal plants create job opportunities, contribute to the development of the pharmaceutical and cosmetology industries, and serve as the basis for natural dietary supplements. They are a source of unique biologically active compounds used in the treatment and prevention of diseases. Cultivating and rationally utilizing medicinal plants promotes biodiversity conservation and ecosystem restoration. Genetic engineering, digital technologies, and new cultivation methods open new horizons for the study and application of medicinal plants. The collaboration of scientists worldwide enables the harmonization of cultivation standards, the exploration of new species, and the preservation of rare genetic resources.

The prospects for using medicinal plants include integration into sustainable development systems, the creation of new biopharmaceuticals with high efficacy and low toxicity, the expansion of digital technologies for research and cultivation monitoring, and the active promotion of knowledge about medicinal plants among the general public.

In summary, medicinal plants remain an inexhaustible source of discoveries, an inspiration for scientists, and a foundation for sustainable development. Their study, cultivation, and application contribute not only to improving the quality of life but also to fostering harmony between humans and nature.

REFERENCES

1. Afonin O.V. (2012) Vdala is a highly productive lavender variety. Science information Bull. completed sciences, development Agrarian science of production. Kyiv,. No. 1'12. P. 16-17.
2. Antoniuk N.E. (1982) Decorative plants of the natural flora of Ukraine. K.: Higher School,. 220 p
3. Belova I.V., Glumova N.V., Karpova G.Ya. (2010) Features of the formation of the protective response of essential oil plants to the effect of low temperatures and the possibility of using exogenous physiologically active substances for their activation. Mate. XI conference of young scientists "Scientific, applied and educational aspects of physiology, genetics, biotechnology of plants and microorganisms Kyiv,. P.18-25.
4. Bilenko V. H., Yakubenko B. Ye., Likar Ya. O., Lushpa V. I. Medicinal Plants: Cultivation Technology and Usage. Textbook. Edited by Dr. of Biological Sciences, Prof. B. Ye. Yakubenko. — Zhytomyr: Ruta, 2015. — 600 p. (Color: 56 p.)
5. Biological Crop Production. — Kyiv: Higher School, 1996. — 239 p.
6. Biotechnology: (2021) achievements and hopes: a collection of abstracts of the 10th All-Ukrainian scientific and practical online conference. Vol. 156 .
7. Bodnar L. M. Natural Plantations and Stocks of Dog Rose Fruits (Rosa canina L.) in Zakarpattia // Bulletin of Zhytomyr National Agroecological University. Scientific-Theoretical Collection, 2012 — No. 1 (30), Vol. 1. — P. 401–406.
8. Bondarchuk L. I. Atlas of Honey Plants of Ukraine. — Kyiv: Urozhai, 1998. — 272 p.
9. Borisova N. A. Determining the Stocks of Medicinal Plant Raw Materials. — Transactions of the Leningrad Chemical-Pharmaceutical Institute. — Vol. 19. — Pharmacognosy Issues. — 3. — 1965. — P. 9–16.
10. Borisova N. A., Shreter A. I. On the Methodology of Accounting and Mapping of Medicinal Plant Resources // Plant Resources. — 1966. — Vol. II. — Issue 2. — P. 271–277.
11. Borodina N. V., Kovalov S. V., Rudnik A. M. Study of Carbohydrates in Aspen (Populus tremula L.) // Phytotherapy Journal, 2006. — No. 3. — P. 49–52.
12. Botanical Atlas. / Edited by Corresponding Member of the USSR Academy of Sciences B. K. Shishkin. — Moscow-Leningrad: Agricultural Literature Publishing House, 1963. — 504 p.
13. Bryhadirenko V. Baikal Root of Life // Ogorodnik. — No. 11. — 2001. — P. 32–33.
14. Brykin A. I., Konon N. T., Korneeva Ye. I., et al. Testing of Variety Crops (Plantations) of Medicinal Plants // Medicinal Plant Cultivation.
15. Burchinskyi S. H., Levytskyi Ye. L., Prymak R. H. Medicinal Preparations: A Popular Dictionary-Reference Book. — Kyiv: Medicine of Ukraine, 1997. — 384 p.
16. Burmaka O. V. Meadow Clover as a Source of Effective Biologically Active Substances // Phytotherapy Journal, 2009. — No. 4. — P. 55–60.
17. Catalog of Completed Scientific Developments of the Department of New Crops. (National Botanical Garden of the National Academy of Sciences of Ukraine). — Kyiv, 2003. — 76 p.
18. Catalog of Medicinal Plants of Botanical Gardens and Arboretums of Ukraine: Reference Guide. / Edited by A. P. Lebeda. — Kyiv: Akademperiodyka, 2009. — 160 p.
19. Cornus A. O. (2013) Geographical assessment of soil fertility of the Sumy region. Scientific notes of the Sumy State University named after A.S. Makarenko Geographical sciences.. Issue 4. P. 35-38.
20. Intensive Technologies for Growing Apple Orchards (Recommendations). / Authors: V. V. Chernii, V. P. Ripamelnyk, O. P. Dovbysh et al. — Bulletin of the Nikitsky Botanical Garden, 2011. — Issue 100. — P. 64–67.
21. Ishchenko M. V. Study of Immunomodulatory Properties of Linden Inflorescences: Impact on Cellular Immunity and Physical Activity // Phytotherapy Journal, 2006. — No. 2. — P. 32–35.
22. Karpuk U. V., Kyslychenko V. S., Dyakonova Ya. V. Determination of Certain Standardization Parameters of Common Corn Leaves // Phytotherapy Journal, 2011. — No. 3. — P. 60–62.
23. Kornus A.O. (2010) Geography of the Sumy region: nature, population, economy. Sumy: FOP Natalukha A.S.,.P 184 .
24. Kovaleva N. H. Treatment with Plants. — Moscow: Medicine, 1971. — 352 p.
25. Kovtun I. M., Markovskyi V. S., Olifer A. F. Berry Crops. — Kyiv: Urozhai, 1991. — P. 29–33.
26. Kozyarin I. P. Famous and Unknown Garlic // Phytotherapy in Ukraine, 2001. — No. 3. — P. 40–42.
27. M. M. Prikhodko (2013) Ecological safety of natural and anthropogenically modified geosystems: monograph. K.: Center for Environmental Education and Information,. 201 p
28. Manushkina T.M. (2012) Physiological features of the development of isolated lavender meristems in IN VITRO culture. Taurian Scientific Herald.. Issue 81. P. 108.
29. Mazur V.A., Pantsyreva G.V., Didur I.M., Prokopchuk V.M. (2018) Lupine is white. Genetic potential and its implementation in agricultural production. VNAU.. P. 231.
30. Minarchenko V. M. Medicinal plants. Encyclopedia of modern Ukraine. URL: http://esu.com.ua/search_articles.php?id=55467

31. Mommy Collection of scientific works of the Vinnytsia National Agrarian University. Agriculture and forestry. (2017).N. 7 vol. 2. Vinnitsa. P. 87-9
32. Potato: Practical Encyclopedia. / Edited by P. S. Teslyuk, M. Yu. Vlasenko, M. Y. Shevchuk; LLC "Institute of Potato Seed Production". — Lutsk: Nadstyria, 2003. — 312 p.
33. Prokopchuk V., Pantsyreva H., Tsyhanska O. (2020) Biostationary and exposition plot of Vinnytsia national agrarian university as educational, scientific and manufacturing base in preparation of the landscape gardening specialist. The scientific heritage.. Vol.51. P. 8-17.
34. Promising directions and innovative achievements of agricultural science (2020): materials of the II All-Ukrainian scientific and practical internet conference dedicated to the outstanding scientist, teacher, organizer of agricultural production, founder of the Kherson Zemstvo Agricultural College, candidate of agriculture and forestry K.I. Tarkhov, ,. Kherson: KhDAU State Technical University,. 201 p.
35. Vasyliev V. P., Shelestova V. S., Antonyuk S. I., Shyshkova M. I. Garden Protection Against Pests and Diseases. — Kyiv: Urozhai, 1976. — 364 p.
36. Velma V. V., Kyslychenko V. S., Omelchenko Z., Bukharina O. V. Main Parameters for Standardization of Black Elder Leaves // Phytotherapy Journal, 2009. — No. 1. — P. 57–59.
37. Veterinary Toxicology: Textbook (Malinin O. A., Khmelnytskyi H. A., Kutsan A. T.). — Korsun-Shevchenkivskyi: ChP Maidaichenko, 2002. — 464 p.
38. Voytyuk Yu.O., Kucheryava L.F. Morphology of plants with the basics of anatomy and cytoembryology. K.: Nauka, 225 p.

THE ROLE HUDRANGEA (*HYDRANGEA* L.) IN ORNAMENTAL GARDENING AND FLORISTRY: PROPAGATION CHARACTERISTICS

Osmachko Olena
Candidate of Agricultural Sciences, Associate Professor, Sumy National Agrarian University, Ukraine
ORCID ID: 0000-0003-0591-2650

Horbas Serhii
Candidate of Agricultural Sciences, Associate Professor, Sumy National Agrarian University, Ukraine
ORCID ID: 0000-0003-3768-8833

Introduction. Different climatic zones of Ukraine are characterized by specific conditions that directly affect the local flora. Therefore, to achieve human comfort, it is necessary to adapt approaches to each climatic region.

Green spaces play a crucial role in creating an ecologically balanced urban environment, contributing to improved air quality, reduced noise pollution, and ensuring thermal comfort. Furthermore, they aesthetically enrich the urban landscape. The design and placement of green spaces require a thorough analysis of climatic, soil, and other natural conditions [1, 2, 3].

Since plants in the landscape are living organisms that are constantly developing and changing, a landscaping specialist must consider these processes when creating projects. Only then is it possible to achieve a harmonious combination of functionality for people and integration into the environment. Creating a harmonious and aesthetically pleasing landscape requires not only careful site planning but also consideration of many factors, such as lighting, soil, site style, and building architecture. An important element is also the correct selection of ornamental plants that will organically fit into the overall composition.

Since each plant species has its unique needs, a phytodesigner must have a thorough knowledge of their characteristics to ensure optimal conditions for their development. This includes not only the selection of suitable soil and lighting, but also taking into account the peculiarities of the terrain and climatic conditions of the area where the plants will be located [4].

Problem statement. To create effective landscape compositions, it is necessary to provide high-quality plant material, proper soil preparation, and strict adherence to agricultural requirements. *Hydrangea*, as an ornamental plant, is not widely used in the landscaping of urban areas and public spaces in all cities of Ukraine, despite its distinct decorative characteristics.

According to research by O.M. Korkulenko, conducted in Kyiv, it was found that species of the genus Hydrangea L. are very rarely found in public green spaces, and their species diversity is poor. Only two species are used in the city's green plantings: *Hydrangea arborescens* L. and H. *macrophylla* (Thunb.) DC. They are found mainly in flower arrangements of street plantings.

The low diversity and insufficient use are surprising, as most species of the genus *Hydrangea* L. have high decorative value, varying winter hardiness, drought resistance, resistance to diseases and pests, and are easy to propagate. The problem of expanding the range of plants for cultivation has always been and remains relevant. A significant role of *Hydrangea* L. in the landscaping of Kyiv and the creation of park compositions belongs to introduced plants. In addition to surveying public green spaces, Korkulenko O.M. studied the assortment of nurseries and garden centers, which are the base of primary introduction in the research area. The range of plants in nurseries does not exceed 32 tree species and 35 shrub species, which in turn contributes to the uniformity of the city's green spaces. The assortment of the genus *Hydrangea* L. in the Teremky Municipal Ornamental Nursery is also very limited and represented only by *H. macrophylla* (Thunb.) DC. The author believes that there is a pressing need to expand the assortment with new plant species and forms, including introduced [2, 3. 5, 6].

Hydrangea impresses with the diversity of shapes and sizes of its flowers, which opens up wide possibilities for its use in landscape design. ones. This characteristic allows for the creation of both miniature compositions for small flower beds and impressive ensembles for large city parks [7, 8].

An important characteristic of the hydrangea is its unpretentiousness and ability to adapt well to the urban environment. It can grow successfully both in well-lit areas and in shaded conditions, if provided with moderate watering and regular fertilization. Thanks to its vibrant and impressive flowers, the hydrangea can instantly transform a space, giving it a special charm. It is perfectly suited for both eye-catching solitary plantings and for creating various visual effects, such as zoning the territory or forming vibrant color spots [7].

According to research by Honcharova A.V., conducted in the conditions of the Sofiyivka Research Park, aimed at determining the decorative properties of the Hydrangea genus representatives, the prospects for their use in landscaping and creating landscape compositions were determined. It was found that the studied plants had prolonged flowering and changed the color of leaves and inflorescences during the growing season. The research author believes that members of the Hydrangea genus can also be used in vertical gardening and for decorating the banks of water bodies, strengthening slopes, as well as ground cover plants under tree canopies [9].

It is worth noting that the hydrangea is an extremely versatile plant, allowing it to be used to achieve various goals in the context of urban greening, from creating individual accents to forming large-scale landscape compositions. Examples of hydrangea use in landscaping are shown in Figure 1.

Fig. 1. *Use of hydrangea in landscaping [10]*

Hydrangea is a true star in the world of floristry, a flower that never goes out of style. Its lush, voluminous inflorescences, resembling clouds, can decorate any event and interior. Thanks to its diversity of shapes, sizes, and colors, hydrangea is a versatile tool for creating various floral arrangements. Its large, spherical, or paniculate inflorescences consist of numerous small flowers, creating an impression of lushness and volume. The diversity of colors – from white and soft pink to rich blue, purple, and even green – allows for the creation of bouquets and arrangements to suit any taste. It is suitable for creating various floral works [2]. Hydrangea can be both the main flower in a bouquet and a wonderful addition to other flowers, such as roses, peonies, and lilies. Its voluminous inflorescences add texture and lushness to the bouquet.

Fig. 2. *Hydrangea bouquets [11]*

Hydrangeas are used to create a variety of compositions – from small table decorations to large installations for decorating festive events. Hydrangeas are also frequently used in wedding floristry. It is popular for making wedding bouquets and decorating ceremonies [1].

Fig. 3. *Hydrangea arrangements [12]*

Hydrangea has a multifaceted symbolism that varies depending on culture and context: in Japanese culture, hydrangeas are often given as a sign of gratitude or apology; in Western culture, hydrangeas can symbolize healing, understanding, and sincerity; the lush inflorescences of hydrangeas can also symbolize wealth and abundance. The color of the hydrangea flower also has its own symbolism: white hydrangea symbolizes purity, innocence, new beginnings, often used in wedding bouquets; pink hydrangea is associated with tenderness, romance, sincere feelings, suitable for expressing love and gratitude; purple symbolizes wealth, luxury, elegance, adds sophistication to the bouquet; green hydrangea embodies renewal, growth, prosperity, gives the composition freshness and naturalness [13, 14].

Hydrangea is a popular flower in wedding bouquets and for decorating ceremonies. There are the following styles of wedding bouquet formation:

1.Classic. For a classic wedding, white hydrangeas with corymb inflorescences paired with white or cream roses and peonies are ideal. This bouquet will suit a traditional wedding dress and emphasize the bride's youth and freshness.

2. Rustic. In this type of wedding bouquet, you can use paniculate hydrangeas, whose inflorescences resemble lilacs in shape, adding contrasting field or similar flowers and greenery. Hydrangeas will provide the bouquet with a vertical architecture and add volume, while various additions will add liveliness. Such compositions look relaxed and natural, which is perfect for weddings in nature or in rural areas.

Fig. 4. *Wedding bouquets with hydrangeas [11, 15]*

3. Modern. In this case, bright inflorescences of saturated shades (for example, deep lilac or red) in combination with exotic plants and succulents of contrasting colors will be suitable. This informal bouquet will emphasize the bride's boldness and originality, creating a striking accent against the overall look. Obviously, such a composition will look harmonious with an appropriate outfit, but not at all with a traditional white dress and veil.

Hydrangea is capable of decorating any event and providing unforgettable emotions. Its use in floristry is limitless, allowing for the creation of unique and unrepeatable compositions

The aim of the work. This study aims to comprehensively analyze the decorative qualities, biological, and morphological parameters of various species and varieties of the genus *Hydrangea L.,* adapted to the conditions of the city of Sumy, to expand the possibilities of their use in landscape design. An important aspect of the research is the study of the effectiveness of various hydrangea propagation methods, including the use of biologically active substances to stimulate the rooting process.

The material for research were: - articles by domestic and foreign scientists; - seeds of three varieties of *Hydrangea* macrophylla сортів (Nikko Blue, Twist-n-Shout, Endless Summer); - *Hydrangea* cultivar plants: Baunti (*H arborescens*), Bobo (*H. paniculata*), Twist-n-Shout (*H. macrophylla*).

Research methods. Phenological observations were conducted to determine the onset and mass ripening of fruits. Bioecological methods were used to determine the dynamics of shoot growth, reproductive capacity, abundance of flowering, and fruiting. Morphological, qualitative, and sowing indicators of seeds were determined to assess their quality. The effectiveness of two methods of hydrangea cultivation, by seeds and green cuttings, was evaluated. During the research, we conducted phenological observations of three hydrangea species: Hydrangea arborescens, Hydrangea paniculata, and Hydrangea macrophylla. To assess the abundance of flowering and fruiting according to the methodology proposed by V. G. Kapper, with a modification by O.A. Kalinichenko, the dates of the beginning and mass ripening of fruits were also determined. Morphological characteristics of *Hydrangea L.* seed were also studied in three varieties: Bounty, Bobo, and Twist-n-Shout. Seed sowing qualities were also determined [11].

In a study conducted using the methodology of Kolesnichenko O. V., two methods of *Hydrangea* propagation were investigated: seeds and cuttings. To increase the rooting efficiency of/ cuttings, growth stimulants heteroauxin, Kornevin, and succinic acid were used [11].

Location and conditions of the research. The research was conducted in the laboratory of Sumy National Agricultural University, located in the southeastern part of the Sumy region, in the city of Sumy, in the Forest-Steppe zone. The landscape of the site where the educational laboratory of horticulture and viticulture is located includes a typical plain with a slight southwest slope, intersected by deep ravines and gullies, often shaped like «saucers». The Psel River flows east of SNAU, approximately 8 kilometers away.

The soil in the research area is typical chernozem with deep bedding, medium loamy granulometry, a small amount of organic matter, and a coarse dusty structure.

The soil in the research area is characterized by the following agrochemical indicators: the soil solution reaction is close to neutral (pH 5,8-6,0), meaning the soil is neither acidic nor alkaline; the humus content in the arable layer is 3.9%; the soil rating is assessed at 79 points, a high indicator of high soil fertility; calcium and magnesium ions predominate in the soil adsorption complex, which also contributes to increased soil fertility; the arable layer has significant reserves of nutrients such as nitrogen (9 mg/100 g soil), phosphorus (14,0 mg/100 g soil), and potassium (6,7 mg/100 g soil). These nutrient reserves are sufficient to meet the needs of fruit and berry crops; the maximum hygroscopicity of the soil is 1.6 meq/100 g, indicating that the soil is capable of retaining a significant amount of water.

The soils in the research area are level, allowing for the cultivation of various agricultural crops without the risk of losing the fertile layer. These soils are typical of the Forest-Steppe of Ukraine, making them suitable for conducting research related to this zone.

Weather conditions during the research period. The climate in the region where the research was conducted is temperate continental. According to long-term data, the average annual air temperature is +7.4°C. The highest temperatures were recorded in July (+38.5°C), and the lowest in January (-36.0°C). Figure 5 shows the meteorological conditions of the 2023 growing season.

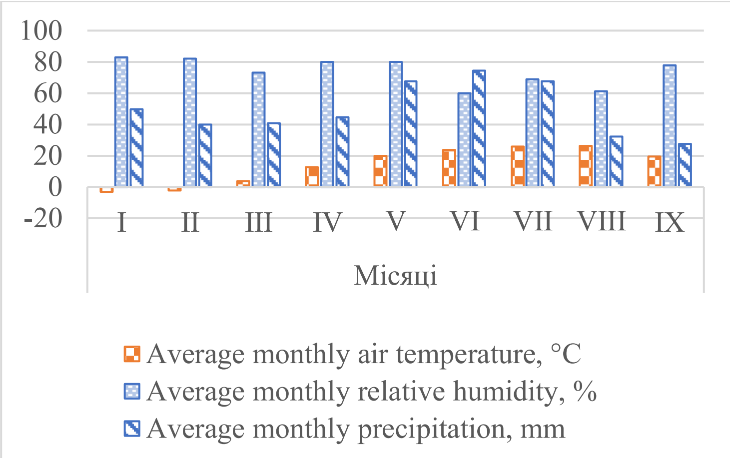

Fig. 5. *Meteorological conditions of the 2023 growing season (according to Sumy meteorological station data)*

The annual sum of temperatures above 10°C is 2500-2650°C. The average duration of the frost-free period is 275 days. Precipitation throughout the year is unevenly distributed, with the highest amount falling in July, averaging 76 mm according to long-term data. In individual years, the amount of precipitation can significantly differ from the long-term average. The total average annual precipitation is 593 mm, and the hydrothermal coefficient ranges between 1,1-1,2.

Thus, the analysis of the 2023 growing season indicates that the soil and climatic conditions of this region are favorable for growing hydrangea species.

Results. We conducted a study of the decorative properties of three hydrangea species: *H. arborescens, H. paniculata*, and *H. macrophylla* (Table 1).

Table 1. Evaluation of the decorative properties of *Hydrangea L.*

Type of culture	Bush form	Height, m	Inflorescence form	Inflorescence diameter, cm	Inflorescence color	Leaf shape	Leaf color
H. arborescens	Round	1,5	Globular	10 до 25	creamy	Large, oval with serrated edges	in summer - deep green, in autumn - bronze hue
H. paniculata	Compact, rounded	1,6	Pyramidal	18-30	first white then pink	elliptical with serrated edges	in summer - deep green, in autumn - bronze hue
H. macrophylla	Spreading, compact	1,5	Flat corymbs	15-25	from white, pink, and red to blue and purple	large, oval or elliptical, with serrated edges	deep glossy green

Hydrangea arborescens is a popular hydrangea species valued for its low maintenance, abundant and long-lasting blooms, and high frost resistance.

The *Hydrangea arborescens* shrub has a rounded, spreading form. It typically reaches a height of 1-1,5 meters. The crown diameter can be approximately the same as the height. The shoots are strong, upright, hold the shape of the bush well, and do not require support, even under the weight of large inflorescences.

The inflorescences are spherical, quite large, with a diameter of 10 to 25 cm, sometimes even larger. The typical color of the inflorescences is white or cream. There are also varieties with pink, greenish, or lime shades. Some varieties can change color during flowering. *Hydrangea arborescens* blooms profusely and for a long period – from June-July to September-October. Flowering occurs on the current year's shoots, which ensures annual abundant flowering, regardless of the severity of winter.

The leaves are large, oval or elliptical, with serrated edges. In summer, they are a deep green color. In autumn, the leaves can take on yellowish or bronze hues, adding to the shrub's decorative appeal in the fall season.

Hydrangea arborescens maintains its decorative appeal throughout the season: in spring – thanks to the fresh green foliage, in summer – thanks to the abundant flowering, in autumn – thanks to the autumn coloring of the leaves and the dry inflorescences, which can remain on the bush throughout the winter, giving it a graphic quality.

Hydrangea arborescens looks great as a solitary plant, in group plantings, in compositions with other shrubs and perennials, and also for creating hedges. It can be used for landscaping parks, squares, and gardens of various styles..

Varieties of *Hydrangea arborescens*: Annabel, Khaies starberst, Baunti, Hrandiflora, Laim Riki. Figure 6 shows photos of *Hydrangea arborescens* varieties.

Hydrangea arborescens Annabelle [16]

Hydrangea arborescens Hayes Starburst [17]

Hydrangea arborescens Bounty [16]

Hydrangea arborescens Grandiflora [18]

Hydrangea arborescens Lime Rickey [16]

Fig. 6. *Photos of Hydrangea arborescens varieties*

In panicled hydrangea (*Hydrangea paniculata*), the bush can have a variety of shapes: from compact, rounded to spreading, with upright or slightly drooping shoots. It typically reaches a height of 1,5-2 meters, with some varieties growing up to 3 meters. The crown diameter can be approximately the same as the height. Shoots are strong, maintaining the bush's shape well, especially in young plants. With age, the shoots may slightly droop under the weight of large inflorescences. The inflorescences are paniculate, pyramidal or conical in shape, consisting of a large number of small flowers.

The flowers of *Hydrangea paniculata* are striking in their ability to change color throughout the flowering period. From initial white or cream shades, they gradually transition to a variety of colors: pink, red, burgundy, lime, or greenish. The intensity and specific shade of the color are influenced by factors such as the plant variety, light level, air temperature, and other growing conditions. *Hydrangea paniculata* blooms very profusely and for a long time – from July to the end of September or even October. Its leaves have an oval or elliptical shape with characteristic serrated edges and a rich green color. In autumn, the leaves of some varieties may change their color to yellow or reddish, although this is not a typical characteristic for all varieties.

Hydrangea paniculata is an adornment to the garden in any season. In spring, it delights the eye with the succulent greenery of its leaves. In summer and autumn, the time of its lush flowering arrives, when the inflorescences gradually change their color, creating a unique palette. And in winter, even after the leaves have fallen, the dry inflorescences, covered with frost, look like delicate lace.

Hydrangea paniculata is perhaps the most well-known type of hydrangea, striking with its large, vibrant inflorescences of various colors. Its decorative appeal is due to many factors.

Hydrangea paniculata varieties: Polar Bear, Limelight, Bobo. Photos of panicled hydrangea inflorescences are shown in Figure 7.

Hydrangea paniculata variety Polar Bear

Hydrangea paniculata variety Limelight

Hydrangea paniculata variety Bobo

Fig. 7. *Photos of Hydrangea paniculata varieties [16].*

Hydrangea macrophylla is the most well-known type of hydrangea, striking with its large, vibrant inflorescences of various colors. Its decorative appeal is due to many factors. The bush is usually rounded or spreading, compact, depending on the variety and growing conditions. Its height typically reaches 1-1,5 meters, and the crown diameter is approximately equal to the height.

Shoots are quite strong, but may require support under the weight of large inflorescences, especially after rain. Inflorescences are capitate (head-like) or corymbose (flat-topped), consisting of a large number of sterile flowers, while corymbose inflorescences have large sterile flowers at the edges and smaller, fertile flowers in the center. In acidic soil (pH 4,5-5,5), inflorescences acquire blue or purple coloration. In neutral or alkaline soil (pH 6,5-7,5), inflorescences become pink or red. White varieties do not change color depending on soil pH. Inflorescences are quite large, reaching 15-25 cm in diameter, and sometimes even more. Bigleaf hydrangea blooms from July to September. The leaves have an oval or elliptical shape with serrated edges. They are large in size, a rich green color, and glossy.

Fig. 8. *Photos of bigleaf Hydrangea macrophylla [8]*

Hydrangea macrophylla varieties: Endless Summer», Nikko Blue, Twist-n-Shout, All Summer Beauty, Pia, L.A. Dreamin. The duration of the decorative period from spring to autumn – thanks to the bright inflorescences. Bigleaf hydrangea is able to decorate any garden with its lush and vibrant inflorescences. Its ability to change color depending on soil acidity adds to its special appeal and allows for the creation of interesting compositions. It is important to consider the specifics of caring for this species to ensure abundant and prolonged flowering

To better understand the developmental characteristics of hydrangea and its response to the environment, we conducted phenological observations on three hydrangea varieties: Bounty (*Hydrangea arborescens*), Bobo (*Hydrangea paniculata*), and Twist-n-Shout (*Hydrangea macrophylla*). The results of the phenological observations are presented in Table 2.

Table 2. Results of phenological observations, 2023

Variety name	Beginning of vegetation	Budding	Flowering		Fruit formation	Onset of dormancy
			Beginning	Completion		
Bounty *(Hydrangea arborescens)*	21.03	9.05	25.06	25.09	20.10	5.11
Bobo (*Hydrangea paniculata*)	30.03	14.05	30.06	4.10	29.10	15.11
Twist-n-Shout (*Hydrangea macrophylla*)	5.04	22.05	6.07	10.10	6.11	30.11

According to our observations in 2023, the average daily air temperature crossed 0°C upwards on March 7th, indicating that the winter period had ended and spring had begun. The snow cover completely melted on March 14th. The beginning of vegetation recovery in 2023 for Hydrangea arborescens occurred on March 21st; during this period, the air temperature consistently exceeded +5°C.

In *Hydrangea paniculata*, the beginning of vegetation occurred on March 30th, and in Hydrangea macrophylla, on April 5th. The first sign of the beginning of vegetation is the swelling of buds on the shoots. During this period, they increase in size and become noticeable. Then, the first leaves appear, and sap flow in the plant intensifies. During this period, it is important to provide hydrangeas with proper care to stimulate their active growth and flowering. Prune the bush, removing damaged and weak shoots. Feed the plant with a complex mineral fertilizer. Provide regular watering, especially in dry weather. Protect the hydrangea from possible frosts if they are forecasted.

The next phase in hydrangeas is budding. During this period, the formation of buds occurs, which precedes flowering. This process in the Bounty variety began in the first ten days of May, in the Bobo variety in mid-May, and in the Twist-n-Shout variety in the third ten days of May. The first sign of budding is the appearance of small, greenish tubercles on the ends of the shoots or in the leaf axils. Over time, these tubercles increase in size and take the form of buds.

For successful budding, hydrangeas require sufficient light, moisture, and nutrients. It is important to provide regular watering and feeding of the plants during this period. During the budding period, it is especially important to protect hydrangeas from frosts, which can damage the buds. It is also recommended to remove weeds and loosen the soil around the plants to ensure air access to the roots. To achieve more lush hydrangea flowering, we removed excess buds, leaving only a few on each shoot. The next phase in the studied varieties was flowering. This phase of plant development occurred in *Hydrangea arborescens* and *Hydrangea paniculata* in late June. *Hydrangea macrophylla* 'Twist-n-Shout' began flowering in the first ten days of July. The beginning of flowering is the phase during which the first flowers open. Mass flowering is the period when most flowers are open. The end of flowering is the beginning of wilting and shedding of flowers. This phase of plant development began first in *Hydrangea arborescens*. The Bobo and Twist-n-Shout varieties finished flowering in the first ten days of October.

The fruit formation phase coincided with the yellowing and leaf fall in the Bounty and Bobo varieties in the third ten days of October, and in the Twist-n-Shout variety in early November.

According to our research in 2022, the cessation of vegetation occurred in *Hydrangea arborescens* in the first ten days of November, in the Bobo variety in the second ten days, and in the Twist-n-Shout variety at the end of November.

Seed yield assessment. Most ornamental flowering plants successfully propagate by seed, although the result can vary depending on environmental conditions, care, and genetic characteristics. As for shrub plants, many of them reach reproductive age as early as 2-3 years, again, depending on growing conditions [18].

Various factors influence the seed quality of many tree and shrub species, including the formation of non-viable or sterile pollen, incomplete pollination due to unfavorable weather conditions, low productivity of the male generative sphere, limited number of plants per area, genetic uniformity, as well as damage by pests and diseases [19].

Ornamental flowering plants can produce seeds with both high and low sowing qualities. In this regard, seed quality analysis, including varietal characteristics, is a mandatory step before its use and during storage [20].

Seed propagation is an effective method for many ornamental plants capable of generative development. However, it should be noted that the inheritance of traits in offspring can be quite variable – from 10 to 60%. Therefore, seedling selection is an important step to achieve the desired result.

Introduction of woody plants is an effective way to enrich genetic material for breeding. Adaptation to new conditions promotes the emergence of diverse variations that can be used to create new varieties. At the age of 1-2 years, seedlings may exhibit changes in leaf color. The advantages of seed propagation include a stronger root system, resistance to diseases and pests, as well as a longer lifespan [18, 20].

To predict future yields and assess the actual productivity of the generative sphere of plants, we evaluated the abundance of generative organ formation in the *Hydrangea L.* genus of three species: *Hydrangea arborescens* Bounty, *Hydrangea paniculata* Bobo, and *Hydrangea macrophylla* Twist-n-Shout.

Hydrangea arborescens has a fruit that is a light brown capsule, which has a spherical shape and ten elongated ribs. It has two divergent columns on top. The fruit diameter ranges from 1.5 to 2.0 mm. The seeds have an oval or broadly elliptical shape, with a bluntly pointed end at the base. The seed surface is longitudinally furrowed, smooth, and glossy [21, 22].

Hydrangea macrophylla is characterized by the following fruit features: a dark gray capsule with three or four divergent columns at the top. The capsule length is approximately 3 mm (up to 4 mm with columns), and the width is about 2 mm. The capsule base has a cone-shaped form and narrows towards the pedicel.

On the calyx surface, elongated-ribbed formations are observed. The seeds have an irregularly oval shape, with no noticeable wing. The seed surface appears finely elongated-furrowed, smooth, and glossy [21, 22, 23, 24].

Hydrangea paniculata is characterized by the presence of a brown, elliptical fruit with 2-3 divergent columns. The length of this capsule ranges from 2.5 to 3.0 mm (about 3.5 mm with columns), and the width is approximately 2 mm. The region under the calyx has elongated ribs. The seeds have a lanceolate shape, with wings attached at both ends. The seed surface appears longitudinally furrowed, smooth, and glossy [3, 6, 21].

To assess flowering and fruiting, we used the methodology proposed by V.G. Kapper (1930), with modifications by O.A. Kalinichenko (1970). In this methodology, each of the six points corresponding to flowering and fruiting is assigned a specific number of generative organs. The fruit ripening time is determined during regular phenological observations [18, 22].

Fig. 9. *Photos of Hydrangea L. seeds*

The research results concerning the beginning and mass ripening of fruits are presented in Table 3.

Table 3. Dates of the beginning and mass ripening of hydrangea fruits

Crop type	Fruit ripening		Number of days from the end of fertile flower blooming to mass fruit ripening
	Beginning	Mass fruit ripening	
H. arborescens	20.10.2023	29.10.2023	113
H. paniculata	29.10.2023	9.11.2023	88
H. macrophylla	6.11.2023	11.11.2023	107

Through phenological observations, we found that *H. arborescens* fruits began to ripen first on October 20 th. *H. paniculata* ranked second in ripening, with its fruits starting to ripen on October 29 th. *Hydrangea macrophylla* fruits began to ripen last.

The harvesting of *H. arborescens* fruits was carried out on October 29 th, and accordingly, *H. paniculata* on November 9 th, and *H. macrophylla* on November 11th.

The results of the flowering and fruiting abundance assessment of the plants are recorded in Table 4.

Table 4. Results of the flowering and fruiting abundance assessment

№ п/п	Species	Flowering abundance, score	Fruiting abundance, score	Fruit harvesting date
1	*H. arborescens*	5,0 (85 %)	4,2	29.10.2023
2	*H. paniculata*	5,0 (93 %)	5,0	09.11.2023
3	*H. macrophylla*	3,0 (60 %)	2,8	11.11.2023

Based on research conducted in 2023, it was found that *Hydrangea arborescens* and *Hydrangea paniculata* had a high level of flowering (5 points), with the crowns of these species covered with generative organs very well, at 85% and 93% respectively. In *Hydrangea macrophylla*, the crown was covered with generative organs by 60% and corresponded to 3 points, a medium level.

The fruiting abundance of the studied species ranged from 5 to 2.8 points. The highest fruiting rate was found in *H. paniculata* at 5 points, the lowest belonged to *H. macrophylla* (2,8 points), and the average was in *H. arborescens* (4.2 points). Seed quality indicators and morphological features of *Hydrangea L.* species are shown in Table 5.

Table 5. Characteristics of seeds of common hydrangea species under the conditions of Sumy city

Variety name and species	Germination rate, %	Seed dimensions, mm		Surface coloration	Weight of 1000 seeds, g
		length	width		
Bounty (*H. arborescens*)	97,0	0,80	0,40	Dark brown	0,030
Bounty (*H. paniculata*)	30,0	2,58	0,50	Brown	0,028
Twist-n-Shout (*H. macrophylla*)	79,0	0,75	0,35	Sand-colored seeds	0,030

Seeds were germinated indoors at a temperature of +18…+20°C on white filter paper. The filter paper was cut, moistened by dipping it in boiling water, and then allowed to drain excess water, and placed in Petri dishes in 2-3 layers. The study was conducted in four replicates (20 seeds in each variant). The highest germination rates were observed in the Bounty variety, 97%. The second position was occupied by the *Hydrangea macrophylla* variety Twist-n-Shout, with a germination rate of 79%. The lowest germination rates were noted in the Bobo variety, a *Hydrangea paniculata* species.

After examining the seeds of three hydrangea species, we noticed that the 'Bobo' variety had the greatest length (seed size 2,58 x 0,50), and the Bounty and 'Twist-n-Shout' varieties were almost the same size. The weight of 1000 seeds in the three species ranged from 0,028-0,030 g.

Features of *Hydrangea L.* seed propagation. For this experiment, seeds of the Hydrangea macrophylla species of three varieties were used: Nikko Blue (blue flowers), Twist-n-Shout (pink flowers), Endless Summer (flowers change color depending on soil acidity, can be both pink and blue).

Fig. 10. *Purchased Hydrangea L. seeds*

First, the seeds were disinfected with manganese. Then, they were placed on damp cotton wool to prepare them for sowing.

Fig. 11. *Seed preparation for sowing*

Fig. 12. *Germinated Hydrangea L. seeds*

Seed boxes were used for sowing seeds. A soil mixture for hydrangeas was purchased, containing the following components: sod soil + leaf soil + sand (1:1:2). Before sowing, the prepared substrate was moistened. Since hydrangea seeds are very small, when sowing them in boxes, they were not covered with soil, but only pressed tightly against it.

Fig. 13. *Sown hydrangea seeds in soil*

After sowing, the boxes with seedlings were carefully watered with a spray bottle, covered with a transparent bag, and the temperature regime was maintained within 18-22 °C. Under these conditions, the air above the seedlings under the bag became saturated with moisture, which contributed to rapid swelling and germination of seeds. The main mass of seeds germinated within 9-16 days after sowing.

After the seeds were sown, further care consisted of ensuring constant air humidity through regular watering with a sprayer. To protect against direct sunlight, the delicate seedlings were grown in shaded conditions. After germination, the seedlings were gradually acclimatized to fresh air. The seedlings successfully developed in diffused light conditions, but poorly tolerated prolonged exposure to direct sunlight.

One of the necessary steps to obtain healthy hydrangea seedlings is transplanting young plants. After they have developed 1-2 true leaves, the seedlings were transplanted into cups filled with the same soil mixture that was used for the initial sowing. Photos of Hydrangea L. seedlings are located in Figures 14 and 15.

Fig. 14. *Pricked-out hydrangea seedlings*

Fig. 15. *Seedlings 6 months of growth Hydrangea L.*

Seedlings were transplanted into moist and loosened soil to the depth of the cotyledon leaves. In the first days, they were shaded to protect them from direct sunlight.

Table 6 shows the sowing and emergence dates of Hydrangea macrophylla seedlings.

Table 6. Average dimensions of six-month-old Hydrangea macrophylla seedlings, cm

Variety name	Sowing date	Seedling emergence date	Average plant height at six months of age, cm
Nikko Blue	10.03.2023	20.03.2023	8,0
Twist-n-Shout	10.04.2023	25.04.2023	5,0
Endless Summer	10.05.2023	22.05.2023	6,5

All varieties of *Hydrangea macrophylla* were sown at different times. The Nikko Blue variety was sown on March 10 th and seedlings appeared after 10 days. The Twist-n-Shout variety was sown on April 10 th, and seedlings were obtained on the 15th day after sowing. The Endless Summer variety was sown on May 10 th, and seedlings were obtained on the 12 th day. All seedlings were grown under the same conditions at a temperature of 18-22 °C and with systematic watering.

The germination date depended on the genetic characteristics of the varieties. The highest average plant height at six months of age was observed in the Nikko Blue variety and was 8 cm. This can be explained by the fact that plants of this variety reach a height of 1,5 m in adulthood. In second place in terms of the height of six-month-old seedlings was the Endless Summer variety, its height was about 6,5 cm, adult plants have a height of 1,2 m. The Twist-n-Shout variety plants were the shortest at six months of age. The height of adult plants of this variety is usually about 90 cm.

Features of propagating *Hydrangea L.* by green cuttings. A common method of vegetative propagation is the use of stem cuttings. The theoretical basis for this method is the results of numerous researchers [25]. The efficiency of the work depends on various factors, such as the age of the mother plants, their successful growth and development, the physiological state of the cuttings used, the timing of harvesting, the method and preparation of the cuttings for planting in the substrate, as well as the conditions created for rooting, and the quality and characteristics of the care of the cuttings [26].

In our research, we used the method of rooting hydrangeas with green cuttings in three periods using growth stimulants. We used well-known root formation stimulants that can be purchased in stores. These products were used in the form of aqueous solutions with the following concentrations: heteroauxin (200 mg/l), Kornevin (2.0 g/l), succinic acid (1 g/l).

Fig. 16. *Green cuttings of Hydrangea L.*

The experiment was conducted in four variants:
Variant 1 – control;
Variant 2 – plants were treated with heteroauxin;
Variant 3 – plants were treated with Kornevin;
Variant 4 – plants were treated with succinic acid.

As a mother plant, bushes of the Bounty variety (Hydrangea arborescens) were used. The results of rooting cuttings are shown in Table 7.

Table 7. Evaluation of rooting of *H. arborescens* cuttings

№	Experiment variants	Loss rate	Cuttings rooting periods		
			15.06.2023	30.06.2023	15.07.2023
			% of rooted cuttings		
1	Control	-	55	65	40
2	Heteroauxin	200 мг/л	72	83	60
3	Kornevin	2,0 г/л	80	90	70
4	succinic acid	1 г/л	67	75	50
HIP_{05}		4,56			

Based on the research results, we observed that the highest rooting success of green cuttings was noted when using Kornevin, while the lowest percentage of rooting was observed in the control group.

Fig. 17. Rooted cuttings of H. arborescens

To better characterize the effect of growth regulators on the rooting of *Hydrangea arborescens*, the obtained research results were grouped into a diagram in Figure 14.

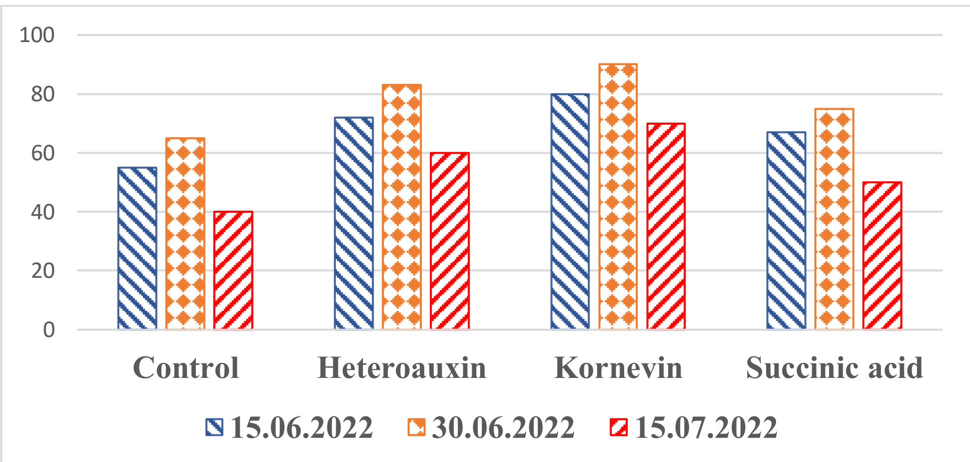

Fig. 18. *Effect of growth regulators on the rooting of Hydrangea arborescens*

It can be concluded that the use of preparations to stimulate root formation has a beneficial effect on the rooting of green cuttings of *Hydrangea arborescens*. Through research, it was found that the best time for rooting *Hydrangea arborescens* is the end of June.

Conclusions.

1.The role of Hydrangea L. in ornamental gardening and floristry was studied and analyzed.

2. The main types and varieties of hydrangea used in ornamental gardening and floristry are described.

3.The aesthetic and functional advantages of hydrangea in landscape design and floral compositions were analyzed.

4. Throughout the growing season, phenological observations were conducted, which showed that the fruits of *Hydrangea arborescens* ripened first – on October 20th. Hydrangea paniculata (October 29th) and Hydrangea macrophylla (November 6th) took second place in terms of ripening. Mass fruit ripening occurred on October 29th in Hydrangea arborescens, November 9th in Hydrangea paniculata, and November 11th in Hydrangea macrophylla.

5. To predict future yields and assess the actual productivity of plants of the genus *Hydrangea L.,* we evaluated the abundance of generative organ formation. *Hydrangea arborescens* and *paniculata* had a high level of flowering (5 points). Hydrangea macrophylla had a medium level of flowering (3 points). The highest fruiting rate was found in the species *H. paniculata (*5 points). The highest seed germination rate (97%) was established in the *Hydrangea arborescens* variety Bounty. The seeds of three hydrangea species, varieties Bounty, Bobo, and Twist-n-Shout, were studied for morphological characteristics. The weight of 1000 seeds in the three species ranged from 0.028-0.030 g.

6. An analysis of the effectiveness of two methods of hydrangea propagation was conducted. The study examined two methods of hydrangea propagation: seed and vegetative.

7. In seed propagation, the fastest shoots appeared in the Nikko Blue variety on the 10th day after sowing. At six months of age, this same variety had the highest average plant height.

8. For vegetative propagation, the method of rooting green cuttings was used. To increase the efficiency of cutting rooting, growth stimulators were used: heteroauxin, Kornevin, and succinic acid.

REFERENCES

1. Ishchuk L.P., Oleshko O.H., Cherniak V.M., Kozak L.A. (2014) Floriculture / edited by Candidate of Biological Sciences L.P. Ishchuk. Bila Tserkva. 292 c.
2. Korkulenko O.M. (2008).Species gender of Hydrangea L. to the rank of turning to be green Kyiv's. *Scientific Bulletin of the Ukrainian National Forestry University: Landscape Architecture in the Context of Sustainable Development*. Lviv: UNFU of Ukraine. Vol. 18.12, P. 249-253.
3. Korkulenko O.M. (2009) Hydrangeas in urban plantings and botanical gardens of Kyiv. Proceedings of the Second International Conference [Introduction, Selection and Plant], (Donetsk, October 6-8, 2009). Donetsk. Vol. 1, P. 361-364.
4. Bessonova V.P. (2010) Plants of flower gardens: a guide. Dnipropetrovsk: «Svidler A.L.» Publishing House. 176 p.
5. Korkulenko O.M. (2012) Bioecological features of the genus *Hydrangea L.* species and prospects for their use in the greening of Kyiv: abstract of a dissertation for the degree of Candidate of Agricultural Sciences: 06.03.01, National University of Life and Environmental Sciences of Ukraine. Kyiv. 22 p.
6. Korkulenko O.M. (2010) Prospects for the use of representatives of the genus Hydrangea L. in green building. *Scientific Bulletin of NULES of Ukraine*. Series: Forestry and Ornamental Horticulture. Issue 152. Part 1. P. 89-94.
7. Bilous V.I. (2005). Ornamental gardening. Uman. 296 p.
8. Kalinichenko O. A. (2003) Decorative dendrology: [study guide]. Kyiv: Vyshcha shkola. 199 p.
9. Honcharova A.V. (2018) Decorative properties of representatives of the genus *Hydrangea L.* in the Right-Bank Forest-Steppe of Ukraine. *Autochthonous and introduced plants.* Issue 14. P. 23-27. [Electronic resource]. Access mode: http://surl.li/jhytvp
10. Photos of hydrangea use in landscaping. [Electronic resource]. Access mode: https://ru.pinterest.com/pin/13159023905161502/
11. Bouquets with hydrangeas. Photos. [Electronic resource]. Access mode: http://surl.li/yvlfar
12. Floristry using hydrangea. [Electronic resource]. Access mode: http://surl.li/ymoeal

13. History and symbolism of hydrangea. [Electronic resource]. Access mode: http://surl.li/qlvyks
14. Most popular shades of hydrangea and their meaning in bouquets. [Electronic resource]. Access mode: http://surl.li/xupvmf
15. Hydrangea in wedding bouquets; tenderness and elegance. [Electronic resource]. Access mode: http://surl.li/yssqau
16. Hydrangea all about planting and care. [Electronic resource]. Access mode: https://svitroslyn.ua/ua/articles/gortenziya-vse-o-posadke-i-ukhode.html\
17. Hydrangea cultivation in the garden, propagation, species. [Electronic resource]. Access mode: https://floristics.info/ua/statti/sadivnitstvo/2176-gortenziya-posadka-i-doglyad-viroshchuvannya-v-sadu.html
18. Myronova H.O., Lavrentieva A.M., Chekalin O.P. (1998) Methodical recommendations for the propagation of woody and shrub plants. Part 1. / Edited by M.A. Kokhn, S.I. Kuznetsov. Kyiv, 1998. 24 p.
19. Korkulenko O.M. (2013) Features of fruiting of introduced species and cultivars of the genus *Hydrangea L*. Scientific Bulletin of UNFU of Ukraine. Vol 23, N 6, P. 267-272.
20. Nikolaeva M.G., Razumova M.V., Gladkov V.N. (1985) Handbook on seed germination of dormant seeds. L.: Nauka, 1985. 348 p.
21. Artyushenko Z.T. (1990) Atlas of descriptive morphology of higher plants: seeds. L.: Nauka, 1990. 204 p.
22. Glukhov O.Z., Dovbysh N.F. Accelerated propagation of uncommon deciduous trees in the southeast of Ukraine. Donetsk: Lebid, 2003. 162 p.
23. GOST 13056.6-75; Introduced 01.01.2000. Kyiv: «Derzhstandart of Ukraine» Publishing House, 1999. 27 p.
24. Hydrangea species. [Electronic resource]. Access mode: http://surl.li/oxvfnf Hydrangea species.
25. Kolesnichenko O.M., Smilyanets N.M., Shumyik M.I. Catalog of promising assortment of trees and shrubs for landscaping Kyiv and suburban area. Kyiv: Phytosociocenter, 2007. 34 p.
26. Hydrangea cultivation in the garden, propagation, species. [Electronic resource]. Access mode: https://floristics.info/ua/statti/sadivnitstvo/2176-gortenziya-posadka-i-doglyad-viroshchuvannya-v-sadu.html

TECHNOLOGICAL ASPECTS OF GROWING SALVIA *POPULUS* × *CANADENSIS* FOR THE CREATION OF FOREST PLANTATIONS IN THE NORTHEASTERN FOREST-STEPPE OF UKRAINE

Tokman Volodymyr
Candidate of Agricultural Sciences, Associate Professor, Sumy National Agrarian University, Ukraine
ORCID ID: 0000-0002-1237-4611

The scientists have performed research and proved that in seven to ten years, the explored oil reserves will be used by approximately 60%, which will lead to a 40% reduction in production. According to world experts, energy consumption will reach more than double by 2050 in the world. In addition, scientists estimate that the world's proven natural gas reserves will last only 60 years, oil - 30 years, and coal - 600 years. Therefore, a great need exists to use unconventional energy sources as an alternative to fossil fuels.

Nowadays, approximately 40% of energy requirements will be met from alternative energy reserves personally about 30% - by bioenergy, which, in turn, should be based the usage of plant mass of a number of highly productive bioenergy crops.

Today, more than 20 types of plants that give energy were researched in Ukraine that could be grown to produce plant biomass. These crops include, for example, fast-growing trees of various types of willow and poplar sorghum, as well as annual and perennial herbaceous plants: sugar cane, miscanthus, amaranth, sharp-edged bitterroot, Sakhalin bitterroot, Pennsylvania mallow, rumex, rod millet, hybrid tobacco, etc.

Ukraine has approximately territory of unproductive land 4.5 million hectares and eroded land that could be used for plantations.

The forest covers almost15%, in Ukraine while in Poland it is 27% and in Finland it is 70%. To significantly increase this indexes, it is essential to make_plantations on an area of at least 1.5 million hectares, including energy plantations, which will be occupied by willow and poplar.

Thus, if energy plants are grown on 1 million hectares and their average yield is 11.5 million tons per year, up to 5.5 billion m^3 of gas can be replaced. Thus, Ukraine can potentially replace about 20 billion m3 of gas with energy crops.

In Western Europe, plants that give energy are cultivated at 117.4 thousand hectares. Such as, this indicator is 18.3 thousand hectares are in Poland or 17.8 thousand hectares are in Germany. According to various estimates, in Ukraine, only 3.5 thousand hectares of fields were given under energy plants.

Among the famous crops for bioenergy purposes is poplar. Poplar is receiving special attention around the world, including in Ukraine.

In general, there are 31.4 million hectares of artificially created plantations of various poplar species all round the world, andthe largest number of them are in Canada (69%) and China (27%) [3].

Research in the field of bioenergy and plantation agriculture in Ukraine is conducted by Y. Fuchylo, Y. Debryniuk, G. Geletukha, T. Zhelezna, V. Litvin, M. Roik, L. Khudoleieva and others.

In the climatic conditions of our country, among other trees, poplar grows the fastest, it is resistant to diseases and cultivation good on non-fertile soil (but 1% of humus is required). In addition, the opportunity of cultivation it on contaminated land has been created.

Nowadays, we have got comparatively quick growing or biomass production, poplar plantations are increasingly using as a regenerative energy source to biofuel manufacture. Timber is easy quite to be extensively exploited for technological target.

Ten tons of poplar wood chips replace 2500 m^3 of natural gas. That's way biofuel will be worth the country practically five times cheaper than gas. Cottonwood absorbs a big number of carbon dioxide, making it perfect sustainably gasoline. Malicious evaporation will drop by 90% relatively to diesel gasoline [16]. At the commercial farm, the harvest of cottonwood dry mass is up to 12 t/ha, and on fertile soils - 20 t/ha [10, 18].

Cottonwood inculcation stay efficient for up to 20 years and anymore, and biomass be able to be collect every three to six years during this period.

The deepening of energy problems in Ukraine requires the search for new energy sources, including wood raw materials from plantations. The real renewable alternative energy source is the wood biomass production. It is gaining particular popularity in Ukraine. Today, the real way out of the critical situation is to intensively use the forestry industry with a focus on growing phytomass in plantation plantations, instead of traditional timber harvesting in artificially created or natural forests.

The need to introduce new approaches in the energy sector makes it important to create plantations that will be used for the production of alternative fuels.

At the same time, the creation of plantations of energy crops will allow to solve a number of problematic issues in the environmental, social and economic spheres.

Object of research - agrotechnics of growing plantation *Populus x canadensis* planting material in the conditions of the Landscape Design training laboratory.

The subject of the research is the biological characteristics of *Populus x canadensis.*

The aim of the study is to research agrotechnical measures for the production of *P. x canadensis* planting material for the creation of forest plantations and protective plantations in the northeastern forest-steppe.

To get the result, the next main tasks were identified:

- to analyze the experience of creating *Populus* plantations using the special literature and practical sources;
- to assess the natural and climatic terms of the northeastern part of the Forest-Steppe regarding their suitability for the creation of *Populus* energy plantations;
- to consider the impact of growing conditions and micropod thickness of the research of the standard of landing material.

City, methodology and research design. The study of the peculiarities of growing annual cuttings of *Populus x canadensis* was done in 2024 in the training laboratory of “Landscape Design” of Sumy National Agrarian University. Lignified cuttings of different thicknesses were used. The cuttings were cut with secateurs from annual shoots immediately before planting. Slices were made perpendicular to the shoot axis. The cuttings have been planted in the middle of April in containers. Throughout the vegetation period, the crops have been regularly watered and weedage were deleted

The cuttings were harvested before the bud swelling phase. The length of plant cuttings reached 90-120 mm. After harvesting micropropagules, they were placed in water for 3 hours. Rooting of the cuttings was plant in a mixture of earth and substrate which consists of mixture of peat and sand in equal proportions. The experimental design combined variants where the factors were the cultivation technology and the thickness of the cuttings. Micropropagules were planted vertically in 1,0 liter pots. The planting depth of the cuttings was 6-7 cm.

Studies were performed according to the following scheme:

Factor A - natural light conditions: 1) control (4,5 mm); 2) 6 mm; 3) 9 mm; 4) 12 mm. Factor B - shading conditions: 1) control (4,5 mm); 2) 6 mm; 3) 9 mm; 4) 12 mm.

In autumn, in the second decade of September, rooting of cuttings and other qualitative indicators were calculated in accordance to the techniques generally accepted in plant growing and forestry [13].

Research results. Asexual reproduction of plants is relatively common in nature, but people use it even more often to propagate plants and their ornamental forms.

For example, *Populus* is unpretentious and easily propagated both by seeds and vegetatively, in particular by cuttings.

In 2024, in the conditions of the cultivation facility of the Department of Gardening and Forestry, experimental work was carried out on the peculiarities of root propagation of *P. x canadensis*.

According to N. Y. Vysotska [18], the processes of callus and corrosion in *P. x canadensis* planting material are quite rapid due to the presence of a hormonal compound in the plant organism that causes the reproduction of the root system.

Table 1. Influence of *P. x canadensis* planting material thickness on root formation ability

No	Variant	Rooting, %	± to control
1.	4,5	98	- 2
2.	6	99	- 1
3.	9	100	0
4.	Control (12 mm)	100	-

The results of the research (Table 1) show that harvesting of the experimental species cuttings before the phase of bud swelling is necessary, and the thickness of the planting material does not affect the value of the regenerative capacity. According to the author's observations, in the conditions of the cultivation facility, the root system of the cuttings is restored within 14-16 days, and the beginning of callus formation begins on day 5-7.

Fig. 1. *Cultivated planting material of P. x canadensis*

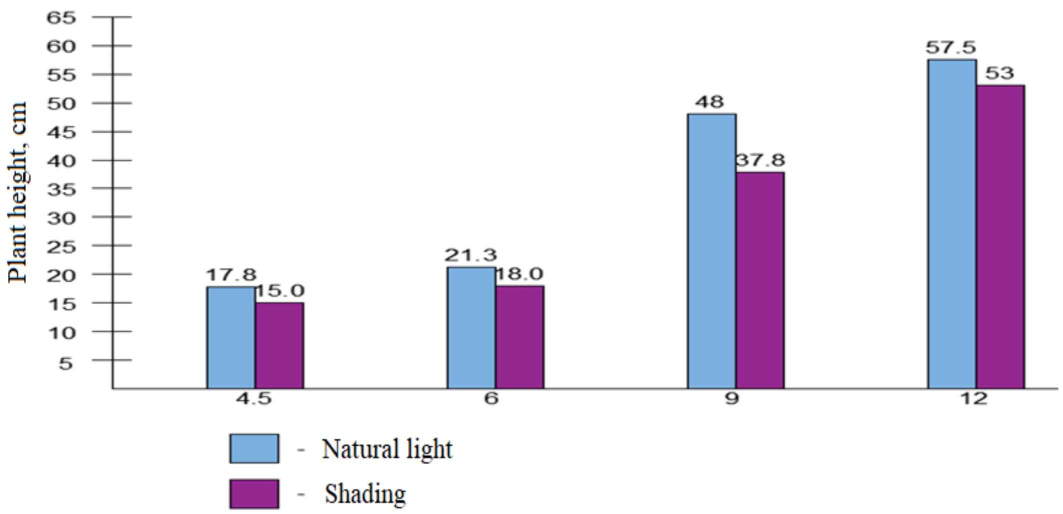

Fig. 2. Height of P. x canadensis plants

Table 2. Influence of some factors on biometric parameters of plants

Growing conditions	Variant	Indicators				
		Length, cm	Weight, g			
			of root system	± to control	of the aerial part	± to control
Natural light	Control (4,5)	17,8	7,1		10,1	
Shading		15,0	6,0		4,0	
Natural light	6	21,3	7,7	+ 0,6	13,26	+ 3,16
Shading		18,0	7,0	+ 1,0	7,0	+ 3,0
Natural light	9	48,0	14	+ 6,9	23,66	+ 13,56
Shading		37,8	10,2	+ 4,2	15,0	+ 11,0
Natural light	12	57,5	19,8	+ 12,7	42,2	+ 32,1
Shading		53,0	16,0	+ 10,0	18,0	+ 14,0

Thus, according to the results of the experimental work, a clear correlation was established that an increase in the thickness of the cutting allows you to get a positive effect on the growing material height (Fig. 1-2, Table 2). Given this, the optimal thickness of micropropagules is 9-12 mm.

It should be emphasized that the degree of illumination affected the size of the plants. When using cuttings with a diameter of 12 mm, the height of the plants was in the range of 53.0-57.5 cm, while in the control variant (4.5 mm) it was 15-17 cm, which is 38-39.7 cm less. There was a significant difference between the control and search variants.

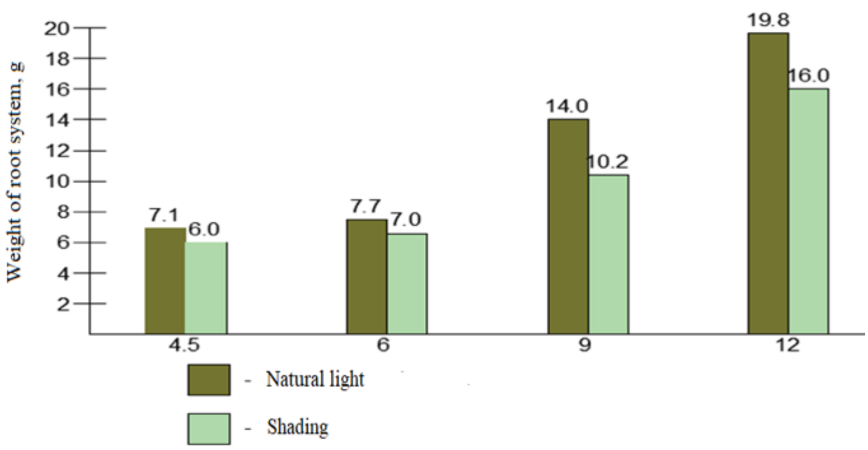

Fig. 3. Root system weight of P. x canadensis planting material

Fig. 4. *Root system of P. x canadensis*

In addition, the relationship between the diameter of the cuttings and_ weight of the root system was analyzed in the research work (Fig. 3-4). When micropropagules with a thickness of 4.5 mm using, the root system weight was in range of 6.0-7.1 g, which is 10 and 12.7 g less than in the variant where cuttings with a diameter of 12 mm were used. The difference in root formation capacity by variant was significant.

According to the table, it should be stated that the weight of the root system of the planting material depends on the growing conditions and the diameter of the cuttings.

Considering the root system at different thicknesses of the planting material, we state that the size of the cutting affects its development. Thus, the root system was compared with the control variants of cuttings with a diameter of 12 mm form a branched that_ is of particular importance for the growth of P. *x canadensis* plants and the absorption of nutrients.

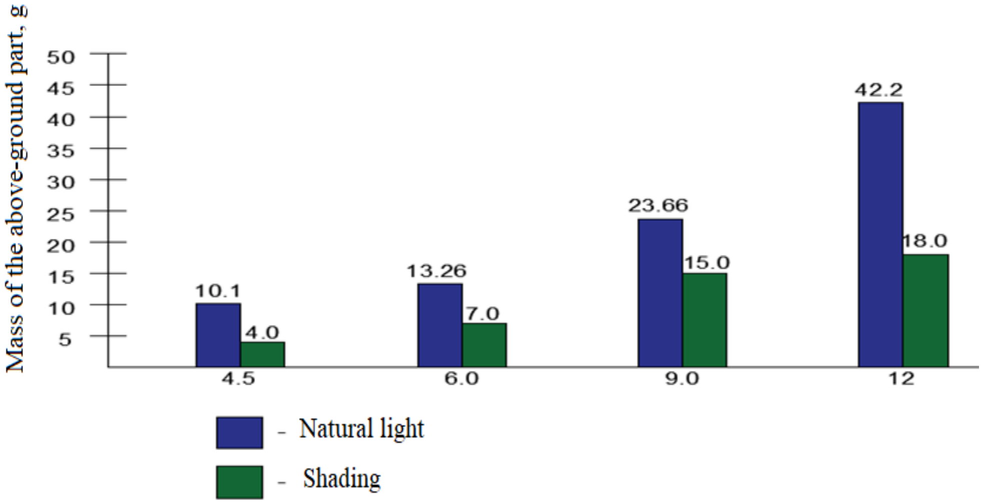

Fig. 5. *Weight of the aboveground part of plants*

When considering the influence of growing conditions and the diameter of the cuttings on the weight of the aerial part of *P. x canadensis* seedlings (Fig. 5) researchers have found important differences between the variants of cuttings. The aerial part plant mass in the planting material ranged from 4.0 to 42.2 g. This figure in the experimental variants was 3.0-32.1 g higher compared to the control.

This figure in the experimental variants was 3.0-32.1 g higher compared to the main indicator.

Concurrently was found that the plants in the control variant had a worse indicator than research samples. It was proved with good lighting and using of larger size of the cuttings, a raise in the weight of the aerial part was observed, which played an important role in physiological processes such as organic matter metabolism and photosynthesis, and also influenced the further development of the plant organism.

According to scientific results, can be said that the growing conditions and the size of the cuttings have a direct impact not only on the height of *P. x canadensis* plants, but also on the weight of the root systems and the aerial parts. It was proved during the experiment, the greatest sizes of *P. x canadensis* plants were obtainedin variant where the experiment was made and where the size of micropropagules was 12 mm.

Scientists have come to a conclusion that for growing seedlings with an uninjured root system, it is worth using cuttings with a diameter of 12 mm.

Scientists from other universities also agreed with the obtained results and they also approved the necessity of applaying micropropagules of the experimental taxon with a thickness of 12 mm.

Photosynthesis is the most important physiological and biochemical action. His role in the existence of organisms is very important, including humans. This process takes place in the leaves. Photosynthesis provides the development of up to 90% of organic compounds. The leaf surface mostly uses ultraviolet and visible solar energy with line length from 300 to 650 nm. On the open territory, just 1-1.5% the amount of sunshine obtained by plants is exploited for the saving of organic substance. The rest of it is used on transpiration_ and heating of the leaf surface.

In our researches the influence of micropod size was proved on the development of the photosynthetic surface (Table 3 and Fig. 6).

Table 3. Effect of growing conditions on photosynthetic surface parameters

Growing conditions	**Variant**	**Leaf weight, g**	**% to control**	**Leaf area, cm^2**	**± to control**
Natural light	Control (4,5)	4,5	-	290,7	-
Shading		2,8	-	224,0	-
Natural light	6	7,03	156,2	340,8	117,2/
Shading		5,3	125	258,0	115,2
Natural light	9	10,8	240,0	523,6	180,1/
Shading		8,3	175	448,0	200,0
Natural light	12	18,7	415,6	906,7	311,9/
Shading		15,8	314,3	800	357,1

During the research on the impact of conditions of growing and cutting diameter on the weight of the leaf seed covering material, a difference was found between the variants. The weight of the leaves on the control variants ranged from 2.8 to 4.5 g, which is 314.3 and 415.6 % less compared to the variante in which 12 mm thick cuttings were using. In the experimental version, the authors claim that, the seedlings had better biometric parameters than others. With the conditions of better light conditions and increased diameter of cuttings, there was a raise in the weight of photosynthetic surface, which significantly affects growth of plant processes and development of plant organism.

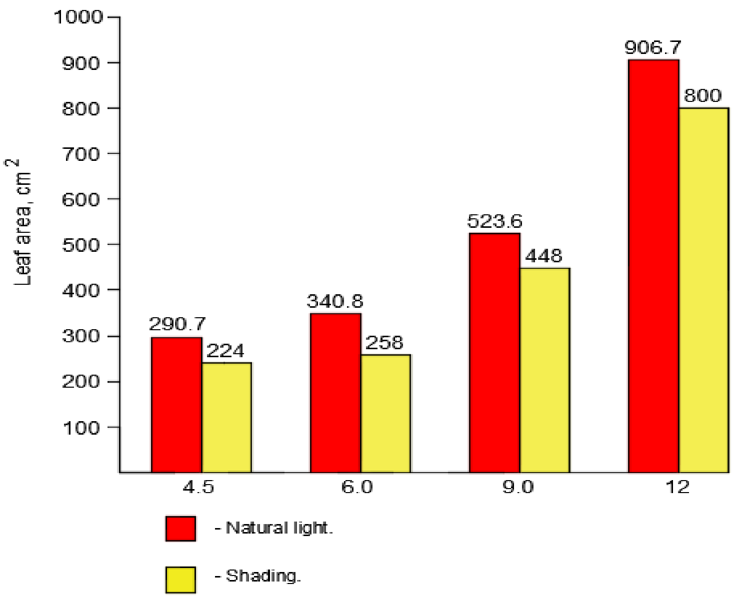

Fig. 6. *Features of photosynthetic apparatus formation in P. x canadensis plants*

During the search work, the light influence supply and the growth of seedlings on the characteristics of leaf surface increase was also analyzed.

The leaf surface of the main group plants was in the range of 224.0-290.7 cm^2, which was 311.0 and 357.1% less than in a experimental version, where 12 mm thick cuttings were used (Fig. 6).

The results of the researches on the influence of micropropagules thickness on the photosynthesizing surface area demonstrated that the highest result was obtained when using cuttings with a diameter of 12 mm. As well, a good impact of lighting conditions on the shaping of the leaf surface was found.

Conclusions and Suggestions For Production

1. *Populus* × *canadensis* is a fast-growing forest species that is grown for the wood production but recently it was using to create plantations.

2. The soil and climatic conditions of Sumy region are suitable for growing *Populus* × *canadensis* planting material with an uninjured root system.

3. It has been found that the quality of planting material of the studied cultivar is influenced by the growing conditions and the diameter of the cuttings:

- the hight of growing plants formed by cuttings with a thickness of 12 mm was 53.0-57.5 cm, which is 33.4 and 63 % more comparing to the main one;
- biometric options of cuttings were affected by the intensity of plant illumination;
- photosynthetic surface area on the control variants was in the range of 224.0-290.7_cm^2, which is 3.5-3.8 times less comparing to the samples where 12 mm thick cuttings were used.

To create forest plantations of *P. x canadensis*, we propose to use planting material with a closed root system. It is capable of forming a significant amount of natural substance. It is more easier to cultivate planting material and is unpretentious to the environment.

REFERENCES

1. Debryniuk Y. M. Plantation forest crops as an element of intensification of forestry production in Ukraine. *Scientific Bulletin of the Ukrainian Forestry Institute*. 2004. Issue 14.5. P. 155-161.
2. Debryniuk Y. M. Plantation forest crops in the Western Forest-Steppe of Ukraine: concept, methodology, resource potential: PhD thesis for the degree of Doctor of Agricultural Sciences: specialty 06.03.01. Lviv, 2007. 40 p.
3. Debryniuk Y. M. Plantation forest plantations as objects of inexhaustible production of energy biomass. *Forestry and agroforestry*. 2009, № 116. P. 170-178.
4. Debryniuk Y. M. Conceptual principles of plantation forestry in Ukraine. *Scientific works of the Forestry Academy of Sciences of Ukraine*. 2013, № 11. P. 25-33.
5. Fuchylo Ya. D., Onyskiv M. I., Sbytna M. V. Biological and technological bases of plantation forestry. Kyiv: NSC IAE, 2006. 394 p.
6. Fuchylo Y. D. Plantation forestry: theory, practice, prospects. Kyiv: Logos, 2012. 463 p.
7. Fuchylo Ya. D., Litvin V. M., Sbytna M. V. Biological, ecological and technological aspects of poplar plantation cultivation in the conditions of Kyiv Polissya. Kyiv: Logos, 2012. 214 p.
8. Fuchylo Y. D., Bordus O. O., Kukosh O. Y., Kyrylko Y. O. Agrotechnical aspects of growing annual cuttings of black poplars in the Right-Bank Forest-Steppe. *Forestry: historical and innovative activities in the field of forestry*. Proceedings of the All-Ukrainian Scientific and Practical Conference dedicated to the 200th anniversary of the birth of V. E. von Graff (November 15, 2019, Ovruch). Malyn: MLTC Publishing House, 2019. P. 87-90.
9. Fuchylo Y. D., Sinchenko V. M., Ganzhenko O. M., Gumentyk M. Y. Methodical recommendations on the technology of growing energy plantations of willow and poplar. Kyiv: CP “Komprint”, 2021. 24 p.
10. Fuchylo Y. D., Kyrylko Y. O., Ivanyuk I. D. Growth and productivity of poplar energy plantations in the conditions of the Right-Bank Forest-Steppe. *Bioenergy*. № 1-2 (19-20). 2022. P. 57-60.
11. Gabrel M. S. Production of solid biofuels in Ukraine: state and prospects of development. *Scientific Bulletin of the National Forestry University of Ukraine*. Lviv: RVV NTU, 2011. Issue 21.9. P. 126-131.
12. Geletukha G.G., Zhelezna T.A., Kucheruk P.P. Current state and prospects of bioenergy development in Ukraine. *Bioenergy Association of Ukraine*. 2014. P. 32.
13. Gordienko M.I., Maurer V.M., Kovalevsky S.B. Methodical instructions for the study and research of forest crops. Kyiv, 2000. 101 p.
14. Khudoleieva L.V., Kutsokon N.K., Nesterenko O.G. Short-rotation plantations of poplars and willows: approaches to reducing the impact on global climate change. *Actual problems of botany and ecology*: materials of the International Conference of Young Scientists (Kherson, June 29 - July 3, 2016). Kherson, 2016. P. 65-66.
15. Kyrylko Ya. O., Fudchylo Ya. D. Influence of the type of planting material on the effectiveness of poplar plantations creation in the conditions of the Right-Bank Forest-Steppe. *Bioenergy*. 1-2 (21-22). 2023. P. 30-33.
16. Litvin V. M. Biological, ecological and technological aspects of poplar plantation cultivation in the conditions of Kyiv Polissya: PhD thesis for the degree of Candidate of Agricultural Sciences: specialty 06.03.01 forest crops and phytomelioration. Kyiv, 2011. 20 p.
17. Roik M. V., Fuchilo Ya. D., Ganzhenko O. M. Theoretical and applied aspects of the use of agroforestry plantations of Ukraine for energy purposes. *Bioenergy.* № 1 (17). 2021. P. 5-8.
18. Vysotska N. Technologies and agrotechnics of creating bioenergy plantations of poplars and willows in Ukraine. *Bulletin of KhNTUA*. 2014. Issue 155. P. 122-126.

ROOTING ABILITY OF STEM MICROPROPAGULES OF *FICUS BENJAMINA* L. AND THE POSSIBILITY OF THEIR FURTHER USE IN INTERIOR LANDSCAPING

Tokman Volodymyr
Candidate of Agricultural Sciences, Associate Professor, Sumy National Agrarian University, Ukraine
ORCID ID: 0000-0002-1237-4611

Ficus is one of the most widespread flowers and ornamental plants, characterized by a huge number of cultivars that were introduced to Europe from America, Africa and Australia [3, 7, 11]. Numerous *Ficus* taxa are unpretentious and relatively shade-tolerant plants that require appropriate soil and air moisture.

Representatives of this genus are beautiful evergreens that can decorate any living space or office [9]. In addition, before the revolution, the attendance of plants of this genus in the house characterized the aristocracy and financial solvency of the owner. Today, there are approximately 800 species of *Ficus* known and each has its own unique beauty [6. 11].

Among the variety of plants grown at home, *Ficus benjamina* is the most famous. These flowers are widely used in office landscaping. and residential premises is thanks to it is the attractive color of its leaves and its ability to create various life forms [13].

Due to intensive growth processes, *Ficus* trees grow to a tree over a meter high in a few years [7, 11]. Large-sized specimens in containers are grown as floor plants, they perfectly green and decorate the interior of large rooms, halls, and offices [4]. New ornamental forms and species of *Ficus* are constantly appearing in the retail network, which increases interest in these plants.

Ficus benjamina is an incredibly popular plant both among indoor plant lovers and among professionals involved in interior landscaping and phytodesign.

Relevance. To date, it is necessary to specify the peculiarities of cuttings in compliance with the biological and genetic characteristics of individual plant cultivars and their decorative forms in different climatic zones, but also find measures that promote regeneration and stimulate the growth in cuttings root system.

The purpose and objectives of the research. The target of the study was to identify the peculiarities of physiological processes in conditions of regenerative capacity in stem cuttings of *F. benjamina* and to perfection some agrotechnical measures for the propagation of the flower and ornamental species in the forest-steppe of Ukraine.

To achieve the purpose, the next tasks were achieved:

- to study the science books about the vegetative method of propagation of *F. benjamina*;
- to identify the optimal timing of cuttings which is based on the biological features of the taxon_ and its decorative forms;
- to consider the peculiarities of using *F. benjamina* plants in interior landscaping.

Object of study - vegetative method of propagation of *F. benjamina* varieties Anastasia and Golden King.

The topic of the_ research is *F. benjamina* Anastasia and Golden King.

Methods of research. The study was carried out at Gardening department and Forestry of Sumy NAU.

Stem cuttings 14-15 cm long were used as planting material for asexual propagation of *F. benjamina*, which was harvested with a part of two-year-old wood (Fig. 1). Micropropagules were placed in water during 2 hours.

Fig. 1. *Cuttings of F. benjamina Anastasia*

The temperature regime during rooting was in the variety of +20 - +25°C, air humidity 65 - 70 %. The mother plants of *F. benjamina* (Anastasia and Golden King) up to 6 years old were used for cuttings.

Search work was performed in two directions:

1. Definition of the impact of the time of cuttings on callus and carogenesis in stem micropropagules of *F. benjamina*.

2. Consideration of the shape effect features on the rhizogenic ability of cuttings.

The scheme of the one research to determine the effect of the term of harvesting of cuttings on the rhizogenesis process in micropropagules included the following options: 1) control (15.03); 2) 15.05; 3) 15.06; 4) 15.08. Micropropagules were harvested from the decorative forms Anastasia and Golden King.

Fig. 2. *Micropod of F. benjamina Anastasia in water*

The harvested cuttings were tied in bunches of 10 pieces and immersed with their lower ends in clean water at 2-4 cm of their length (Fig. 2).

The scheme of the second experiment to determine the effect of varietal_characteristics of *F. benjamina* plants on the root process system recovery included the following variants: 1) control (Anastasia); 2) Golden King.

The research work was performed in compliance with the procedure for the propagation of flowering and ornamental plants of the Botanical Garden of NUBiP of Ukraine [8].

Results of the research. Plant reproduction is the main biological features of the organism, conclusive in the making of a new generation. Their essence is that the role of one individual to form such generation [1, 12].

Plant reproduction has two methods: sexual and vegetative. The foundation of vegetative reproduction is the regenerative ability of plants to restore lost organs. During root propagation, a new generation is reproduced from somatic cells or tissues. Nowadays, the hereditary features_are fully preserved [12].

The main methods of root propagation of plant organisms of the *Ficus* genus in artificial conditions are rooting of micropropagules, cuttings and grafting. The most promising is reproduction by stem micropropagules, which is based on root reproduction and is appropriate for commercial production of rooty plants. It has been established to take root ability of a plant organism is conditioned by genetic features, but largely depends on a lot of different factors (cuttings and age of parent plants, the time of cuttings, the using of exogenous auxin stimulants, environmental factors. Cuttings harvested from plants of various ages and parts of the stem from the same part of the plant organism are characterized by physiological heterogeneity [1, 12].

A film is formed on the surface of the cut, under which cells divide vigorously and later form a callus.

The pocedure of callusogenesis began on day 18 (Table 1 and Fig. 3) under the conditions of root propagation of Anastasia variety on the control variant.

Table 1. Impact of the scion period on the processes of callus and correlation of *F. benjamina* Anastasia

No	Variant	Term of occurrence, days	
		Callusogenesis	Root formation
1.	Control (15.03)	18	30
2.	15.05	17	32
3.	15.06	20	38
4.	15.08	-	-

Fig. 3. *Rooted cuttings of F. benjamina Anastasia*

In some experimental variants, the starting of this process almost did not differ from the control, but at 15.08 the procedure of callusogenesis was not noticed. The next process after callusogenesis is the procedure of the root system formation.

We have noticed the procedure of root system formation in the experimental variants (15.05 and 15.06) began 2-8 days later than in the control.

The review of the experimental results strongly revealed that the researched_period of micropropagation influences the processes of root system recovery in Anastasia cuttings. Early harvesting of cuttings creates prerequisites for a significant increase in their reproductive capacity than the implementation of this measure lately.

The research work results of the learning regeneration ability of Golden King planting material you can see in Table 2 and Fig. 4.

Table 2. Impact of the scion period on the procedure of callus and carogenesis of Golden King variety

No	Variant	Term of occurrence, days	
		Callusogenesis	Root formation
1.	Control (15.03)	26	41
2.	15.05	24	40
3.	15.06	29	46
4.	15.08	-	-

Fig. 4. *Rooted cuttings of Golden King variety*

It was found in the results of scientific work that cuttings are an allowable measures for planting production material for the investigated taxon. It was researched that the callusogenesis processes begin to occur on day 24-29 (at early harvesting of cuttings). The procedure of callusogenesis are followed by root formation. In the researched variant the root system formation started on day 41, and in the experimental option - on days 40-46.

During the research, it was discovered that the *F. benjamina* variety with variegated leaves rooted worse. It is likely that the low chlorophyll content affects the rate of some physiological processes (callus and correction).

The effectiveness of the reproductive cuttings capacity is judged by the intensity of root system growth and the extent its branching. For this purpose, we measured the length of roots on micropropagules of *F. benjamina* of some varieties. The results of scientific researches you can see in Table 3.

Table 3. Influence of varietal characteristics of *F. benjamina* plants on root growth of framework of micropods

No.	Variation	60 day	80 day	100 day
		Extent of the root framework, cm		
1.	Control (Anastasia)	4,7	6,4	7,7
2.	Golden King	3,1	4,3	5,5
NSR_{05}		0,28	0,31	0,26

During the research, scientists discovered various characteristics of *F. benjamina* affect on the root system formation of planting material. After 60 days 60 the the root system length in the control variant was 4.7 cm, and in the experimental version - 3.1 cm, which is 1.5 times less. There was a considerable distinction among the options (NSR_{05} was 0.28).

They noticed on the 80th and 100th day after the cuttings were made, the above trend was monitored. In the research, a considerable difference was noted by variants (NSR_{05} was 0.31 and 0.26).

Analyzing the data obtained, it can be assumed that that varietal characteristics of *F. benjamina* are an important factor that directly affects of the root system length.

Cuttings of the Anastasia variety formed a root system of bigger length than the planting material of the variegated Golden King variety.

Fig. 5. *Variegated forms of Ficus*

Previously, *Ficus* were widely used for landscaping, but then they were forgotten [3-4, 9]. Nowadays, they are gaining popularity again, especially variegated forms, which are a means of interior landscaping (Fig. 5).

The placement of phytocompositions makes the room look more natural. With the help of phytocompositions anyone can create individual decorative elements and partitions. Plants can help to make an unattractive office look more comfortable and pleasant for employees.

The attendance of tall decorative plants in the office changes the atmosphere and purifies the air [13-14].

Fig. 6. *Using large-sized planting material*

Large single specimens are applayed in department interiors. They attract the attention of visitors, change the decor of the space [2, 5, 10]. Large plants look great on the surface of any auditorium or in the lounge of the building. (Fig. 6).

Fig. 7. *Using Ficus in interior landscaping*

Ficus are good plants for interior decoration. Tree-like species (*F. elastika, F. lyrate, F. benghalensis* and others) are well combined in group compositions with other species and decorative plant forms (Fig. 7-9). They are beautiful in the decor of large or medium-sized rooms, sanatoriums, winter gardens, etc. For large rooms, it is recommended to use specimens of plants more than one and half meter high are used [2, 14].

Fig. 8. *The exploit of Ficus in landscaping design*

Fig. 9. *The Ficus using in interior landscaping*

Weaving plants are used for wall decoration. Modern technologies are used to create phyto-pictures that harmoniously combine plants of ornamental plants of various types. Vertical landscaping involves using of ampelous plants that can cling to supports with their leaves or shoots and leaves. This group of plants doesn't need any special conditions and care and is relatively resistant to lack of light [5].

Fig. 10. *Using Ficus in interior landscaping*

F. radicans, *F. montana*, and *F. pumila* are used as ampelous plants to decorate medium-sized or small rooms besides creating phyto-walls in winter gardens (Fig. 10). In addition, they can be used for landscaping industrial premises [9].

Ficus has a favorable affects the quality of room climate in a living space, thanks to its biological characteristics, the house is cleansed of harmful compounds. Indian folk medicine convincingly proves that the plants using of this genus improves the energy of a building and can also cleanse it of negative emotions. The Thai and Chinese nationalities believe that *Ficus* is a guardian of family well-being [7, 11].

In living conditions, *Ficus* needs enough light but it is resistant grows well and develops in conditions of light deficit, but in strong shading, shoots are drawn to the light source and the plant misses its ornamental look [11]. In such way, you are recommended to provide artificial lighting. To preserve the color of variegated forms, they need a sufficient amount of light.

The optimum air temperature for *Ficus* plants is 20-23°C in summer and 18-20°C during winter. It is especially important to protect them from drafts. They react quickly to sharp fluctuations in air temperature and soil hypothermia [7].

When the air in the room is dry, you are recommended to spray the plants with water of moderate room temperature. While watering *Ficus*, it is important to monitor the soil condition, watering it as needed. Excess moisture causes the root system to rot and the plant can die at last.

For planting different species and their decorative forms, a slightly acidic soil mixture is used. It should include peat, sand and leafy soil. Every year, young plants are transplanted, and large specimens, if necessary, increase the container or replace the top layer of the soil mixture with a more fertile one [11].

Conclusions and Suggestions

1. Plants of the family *Ficus* are propagated by seeds, rooting of cuttings, layering and tissue culture. The best is the propagation by lignified micropropagules. You can found micropropagules on the recovery of the root system. Just like you can adapt for the manufacturing of planting material in large quantities.

2. Varietal characteristics, the time of cuttings are stimulating factors of root formation in lignified cuttings of *F. benjamina*. In the researched variants (15.05 and 15.06), root formation processes began 2-

8 days later than in the control. The planting material which we have got of Anastasia variety formed more longer root system than the cuttings of the variegated Golden King variety.

3. The extensive quantity of species and their varieties creates the prerequisites for the widespread use of *Ficus* in landscaping. It has a special look in home interiors and office landscaping. Having created optimal terms for the increase_ and growth of plants,_ they will delight people with their appearance and decorative features.

We suggest rooting *F. benjamina* planting material in March-June. Founded on the botanic and biological species features of studing, it is advisable to use it widely in interior landscaping.

REFERENCES

1. Batygina T. B, Vasylieva V. E. Reproduction of plants. Kyiv, 2002. 232 p.
2. Bilodid Y. M. Fundamentals of phytodesign: a textbook. Kyiv: Parapan, 2004. 240 p.
3. Borisova E. All about indoor plants: a reference book about more than 500 species of indoor plants. Kyiv, 2001. 319 p.
4. Grunwald V. Popular indoor plants: common species, varieties and hybrids Kyiv: SZKEO “Crystal” LLC, 2006. 208 p.
5. Danilenko V. Y. Design: a textbook. Kharkiv: KHDADM, 2003. 320 p.
6. Yelenevsky A. G, Solovyova M. P, Tikhomirov V. M. Botany. Systematics of higher plants. Kyiv: Akademia, 2004. 432 p.
7. Ischuk L. P, Oleshko O. G, Cherniak V. M, Kozak L. A. Floriculture. Bila Tserkva, 2020. 292 p.
8. Maurer V. M, Kushnir A. I. Methodical recommendations for the propagation of woody ornamental plants of the Botanical Garden of NUBiP of Ukraine. Kyiv: NUBiP, 2008. 55 p.
9. Mkhitaryan N. M. Man and comfort. Kyiv: Naukova Dumka, 2005. 396 p.
10. Prokopchuk V. M., Didur I. M., Pantsyreva G. V. Features of the selection of ornamental crops of closed environment for the design of phytomodule in the interior. *Agriculture and forestry*. 2019. № 12. P. 142-153.
11. Sleptsov Y. V., Yakubenko B. E., Bogdanova V. D., Pozdnikov I. O., Andrusyk R. V. Indoor floriculture: a textbook. Kyiv: Condor, 2016. 174 p.
12. Terek O. I. Plant growth: a textbook. Lviv: Ivan Franko National University of Lviv Publishing Center, 2007. 248 p.
13. Tumanov I. M. Interior greening. Methodology of scientific approach. *Scientific Bulletin of NLTU*. 2006. Issue 16. P. 253-270.
14. Chkhartishvillin N., Snizhko V. Interior greening. Kyiv: Alterpress, 2007. 336 p.

INFLUENCE OF FACTORS ON THE EFFECTIVENESS OF VEGETATIVE PROPAGATION OF SOME SPECIES OF ORNAMENTAL PLANTS

Tokman Volodymyr
Candidate of Agricultural Sciences, Associate Professor, Sumy National Agrarian University, Ukraine
ORCID ID: 0000-0002-1237-4611

The preservation and enrichment of vegetation with highly decorative cultivars and forms in the urban environment is very important. Protection of environment is an important task that is closely related to human health. Solving this problem it is necessary to expand the exploit of plantations for green construction and landscaping of various territories.

The development of decorative landscaping is hampered by the shortage of high-quality planting material of the above-mentioned species. Eventually, an important task for today is also the development of agrotechnological) measures for the accelerated production of planting stuff, given the biologic and botanic features of crops and soil and climatical conditions.

The goal of the research. Improvement of technical methods of vegetative propagation of various types of ornamental plants, obtaining rooted cuttings for further cultivation and use in the improvement of recreational objects.

The implementation of the purpose leads to the definition and decision of the next tasks:

- analyzing the literature on the features of distribution of decorative plant species and their forms;
- to research the effect of the substratum on the rooting process of some plant types;
- to research the regeneration ability of cuttings of ornamental plant species depending on the time of their harvesting;
- to use the effect of a biologically active compound on the regeneration ability of microshoots of ornamental plant species;
- to research using of ornamental plants in the improvement of recreational acilities.

Object of research: measures for growing ornamental planting material.

The subject of research: peculiarities of vegetative propagation of ornamental plant species in artificial fog conditions.

Research methods. The research work was performed in the academic building with the educational laboratory "Landscape Design" of Sumy National Agrarian University. To research the regeneration ability of micropropagules (doi.org) of ornamental species, mother plants aged 7-10 years were used. The length of the cuttings ranged from 5 to 12 cm. The prepared cuttings were planted in ridges in the conditions of a cultivation structure.

The research work investigated the influence of soil mixture during the period of cuttings harvesting and an auxin compound (Rhizopon) on the process of root system regeneration.

The search work was conducted using the following scheme:

Factor A - type of substrate: 1) control (humus + sand + peat); 2) forest soil; 3) (peat + sand). Factor B - term of cuttings: 1) control (5.04); 2) 25.06; 3) 5.08. Factor B - physiologically active compound: 1) Rhizopon; 2) control (water).

Planting material should be planted from length of 6-12 cm between each other, and 10-13 cm between rows. Harvested cuttings were planted in the compound of soil to a depth of 3-6 cm. The explore was recurring four times.

High humidity of the substrate was maintained by daily watering for 60 days, and then the soil mixture was moistened as needed.

The search work was conducted using the way of plant reproduction [8].

Research resalts. During the period of vegetative propagation of plants, it is necessary to create conditions for the restoration and formation of the cuttings root system [2-3, 9-10, 12]. An important key to this process is optimal environmental conditions (Table 1).

The results of the research in general prove that the maximum rhizogenic ability of micropropagules of ornamental plant species was documented in the option_ where sand mixture and peat was exploited as a substratum, and the minimum value was recorded in other variants.

The high content of nutrients in the medium negatively affects the rhizogenic ability of micropods of experimental species. Probably that the agrophysical features of the substratum also affect the process of reproduction of the root system [12].

Table 1. Effect of substratum on the regenerative ability of scion

Variant	Plant species	Rooting, %	± to control
Control (peat + sand + humus)	*Cotoneaster horizontalis*	21	-
	Juniperus scopulorum	0	-
	Berberis thunbergii	0	-
Forest land	*Cotoneaster horizontalis*	60	+ 39
	Juniperus scopulorum	5	+ 5
	Berberis thunbergii	3	+ 3
Sand + peat	*Cotoneaster horizontalis*	90	+ 69
	Juniperus scopulorum	9	+ 9
	Berberis thunbergii	10	+ 10

The intensification of the manufacturing process for growing plant seedlings and their ornamental forms is becoming increasingly important through to the busy demand for it. Harvesting of living material in favorable periods provides an opportunity to control biochemical reactions that take place in micropropagules, and also greatly improve the cultivation technology [2, 7].

Table 2. Impact of the propagation harvesting period on the regeneration capacity of landing stuff

Harvesting time propagation	Variance	Rooting, %	± to control
Control (5.04)	*Cotoneaster horizontalis*	90	-
	Juniperus scopulorum	9	-
	Berberis thunbergii	0	-
25.06	*Cotoneaster horizontalis*	87	-3
	Juniperus scopulorum	3	-6
	Berberis thunbergii	10	+10
5.08	*Cotoneaster horizontalis*	12	-78
	Juniperus scopulorum	0	-9
	Berberis thunbergii	0	0

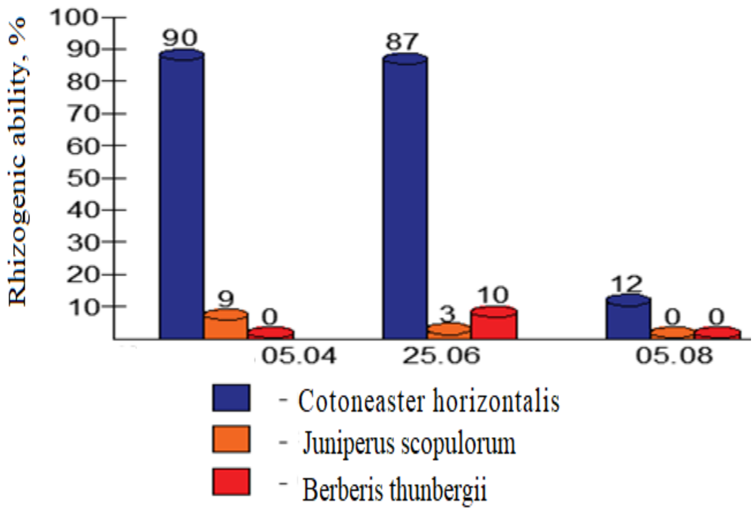

Fig. 1. The impact of the time of harvesting cuttings on their ability to regenerate

The results of the experimental labor (Table 2 and Fig. 1) show that when cotoneaster horizontal cuttings were harvested in April (5.04), the regenerative ability was_ 90%,_ and for another type was minimal.

The cuttings of barberry thunberg after the flowering phase (25.06) provided the maximum index of rhizogenic ability, relative to other terms of micropropagules harvesting.

The rooting rates of ornamental plant species were minimal under the settings of cuttings in August.

With asexual propagation of hard-rooted cultivars, and in particular the ornamental forms of *Juniperus scopulorum* and *Berberis thunbergii*, the task of activating the processes associated with callus and correction by using exogenous growth regulators that can regulate the reproductive capacity of cuttings appears [2, 12].

It has been majored and proven that physiologically active compounds are analogs of antagonists or plant hormones that have the capacity to substitute the ratio of hormonal substances in the body [3]. Using of these combinations creates the foundation for controlling processes which are closely related to callus and correction, as well as understanding the capabilities of the plant organism [7, 10].

According to P. J. Davis [3] and some other scientists [2, 9, 12], activation of the regenerative potencial of microshoots using exogenous analogues of phytohormonal compounds indicates that the regenerative potencial of cuttings is affected by the amount of auxin compounds in the plant (onlinelibrary.wiley.com) organism.These substances exert their effect in interaction with other biologically active compounds. Nowadays rhizogenic ability of micropropagules can reproduce the root system is determined according to the content of auxin-like and other phytohormonal substances, but also by their ratio [3, 7].

According to V. L. Kretovych [7], the increase in the regeneration capacity of cuttings is closely connected with the activation of biochemical reactions and the moving of soluble compounds to the basal part.

Table 3. Plant growth effects regulator on the reproductive capacity of cuttings

No.	**Experiment variant**	**Plant species**	**Rooting, %**	**± to control**
1.	*Rhizopon*	*Cotoneaster horizontalis*	98	+ 8
		Juniperus scopulorum	73	+ 64
		Berberis thunbergii	79	+ 69
2.	Control (water)	*Cotoneaster horizontalis*	90	-
		Juniperus scopulorum	9	-
		Berberis thunbergii	10	-

The exogenous effect of auxin hormones on the cuttings creates prerequisites for cell differentiation, which are necessary for active restoration of the root system and its further growth [3, 10], and also the growth of the aerial part of rooted micropropagules (Table 3).

The research results proves that Rhizopon, in the studied concentration, can affect the processes of callus and corrosion in the planting material of ornamental plant species. The researches of species have shown the best results were got while treating cuttings of *Juniperus thunbergii* and *Berberis thunbergii*.

The rhizogenic capacity of *Berberis thunbergii* cuttings was 10%, in the control variant and 79% of cuttings rooted in the experimental variant which is 69% more than in the control variant. While using the above compound on *Cotoneaster horizontalis*, the above figure was only 98%.

Thus, the using of Rhizopon for the cuttings treatment of ornamental plant species provides an increase in the capacity of grown products.

Fig. 2. *Clones of Berberis thunbergii*

Changes in the amount of hormonal compounds in planting material under the effect of Rhizopon affect the process of root system reproduction than cuttings without the using of this compound.

Landscaping of gardens and parks is impossible without the using of coniferous and deciduous species, they give the surrounding landscape an attractive appearance. *Berberis thunbergii*, *Juniperus scopulorum* and *Cotoneaster horizontalis* are the leaders among the ornamental species used for landscaping open areas. Their important advantages include the appearance of some variations of ornamental forms, the appearance of crowns and their color, unpretentiousness to the urban environment, no need for haircuts, in addition to that slow growth and plants development [1, 4-6, 11].

The following varieties of *Berberis thunbergii* are very popular: Auricoma, Superba and Silver Miles (Fig. 2). Due to the usage of decorative forms with different colors of needles and crown appearance: Skyrocket (Fig. 3), Moonglow, Blue Arrow - *Juniperus scopulorum* occupies a special place in ornamental gardening.

Fig. 3. *Juniperus scopulorum Skyrocket*

Skyrocket resembles the Moonglow variety at a young age, but can grow up to 5 m in height and have a crown up to 2.0 m wide (Fig. 3). It has a dense columnar crown with blue-green needles and branches pressed against the central conductor that point upward. It is a widespread variety: it is not very picky about soil, it prefers sunny areas, and is relatively wind-resistant. It is used for hedges, tapeworms and group plantings in landscape design, *Juniperus* needles saturate the air with phytoncides, this process has a detrimental effect on pathogenic microflora and purify the air. Skyrocket is very easy to take care for, requiring low-intensity watering.

Fig. 4. *Tapeworm plantings of ornamental plant species*

The studied plant species can grow in tapeworm plantings, since in landscape design they are self-sufficient and must not be surrounded by other taxa of plants (Fig. 4). In tapeworm plantings, the bushes are placed in the center of the sod-forming cover or in the relaxion area between the benches.

Fig. 5. *Group plantings of Juniperus scopulorum*

Nevertheless if you have the opportunity and desire to create compositions, it will be the perfect option. Experimental plants are planted in groups, they go well with other deciduous and coniferous species (Fig. 5). Nowadays, *Juniperus scopulorum* takes center stage in the compositions. To give the site a special decorative effect, brightly flowering taxa are planted next to it. In addition, undersized plant species are planted between them.

Fig. 6. *Using Berberis and Cotoneaster in rockeries*

Ornamental plant species are applayed in the design of borderlines, rockeries, alpine hills, they are beautiful in combination with different plant species (Fig. 6). This is facilitated by a fairly great amount of clones that differ in color, heightof the leaves and crown habit.

Fig. 7. *Cotoneaster horizontalis in landscape design*

Cotoneaster horizontalis in landscape design is a highlight for alpine rockeries and slides, where it is used in combination with other ground cover and flowering plants to create attractive compositions (Fig. 7).

Early flowering plant species are planted next to cotoneaster: daffodils, crocuses, etc. Its low-growing varieties look attractive with conifers: *Picea canadensi* and *Taxus baccata. Berberis* is planted in rose gardens or flower beds in combination with other plants; compositional combinations with flowers look especially decorative (Fig. 8).

Fig. 8. *Berberis thunbergii in a flower bed*

Conclusions and Suggestions

1. The regeneration capacity of cuttings of ornamental plant forks depends on the different types of soil and substrate, biological features of the cultivar, the period of harvesting micropropagules, and the using of plant growth regulators.

2. To root the cuttings of decorative plant species it is required to applay a mixture of sand and peat.

3. Cotoneaster horizontalis belongs to the easy-rooted species and should be propagated during April-June.

4. It is advisable to harvest micropods of *Juniperus scopulorum*
should be harvested in April (the regenerative ability was 9%).

5. Cuttings of *Berberis thunbergii* should be carried out after the flowering phase (the index of rhizogenic ability was 10%).

6. An effective plant growth regulator is Rhizopon for the reproduction of the root system in micropropagules of ornamental plant species.

7. The studied plant species and their decorative forms are used everywhere in rock gardens, hedges, borders, tapeworms and group plantings. You also should remember that color of the needles and leaf surface of plants is so diverse.

For the plant material production of ornamental plant species, we propose to use auxin substances. Considering the ecological and botanical properties of the studied varieties, there is a necessity for their widespread use in the creation of recreational areas.

REFERENCES

1. Aksenov E. S., Aksenov N. A. Ornamental garden plants. Kyiv: ABF/ABF, 2000. 608 p.
2. Balabak A. F. Root propagation of garden plants in the Forest-Steppe of Ukraine: PhD thesis for the degree of Doctor of Agricultural Sciences. Kyiv, 1995. 46 p.
3. Davies P. J. Plant hormones biosynthesis, signal transduction action Dordrecht; Boston; London: Kluwer Academic publisher, 2004. 750 p.
4. Glazachev B. O., Pushkar V. V. Manual of the master of green economy. Kyiv: Technika, 2006. 184 p.
5. Zayachuk V. Ya. Dendrology: a textbook. Lviv: Spolom, 2014. 675 p.
6. Kokhanovsky V. M, Melnyk T. I, Kovalenko I. M, Melnyk A. V. Decorative dendrology: a textbook. Sumy: FOP Tsioma SP, 2020. 263 p.
7. Kretovych V. L. Biochemistry of plants. Kyiv: Higher School, 2006. 504 p.
8. Maurer V. M, Kushnir A. I. Methodical recommendations for the propagation of woody ornamental plants of the Botanical Garden of NUBiP of Ukraine. Kyiv: NUBiP, 2008. 55 p.
9. Reva M. L. Vegetative propagation of woody and shrubby plants in natural conditions. Kyiv: Naukova Dumka, 2007. 215 p.
10. Terek O. I. Plant Growth: Study guide. Lviv: Ivan Franko National University of Lviv, 2007. 248 p.
11. Shuplat T. I. Vitality and urban ecological role of bush yalivts in the developed village of Lviv: author's abstract. dis. on health sciences. channel stage S.-G. Sciences 03.00.16 “Ecology”. Lviv, 2019. 18 p.
12. Tokman V. Optimization of elements of cultivation technology of ornamentals in the Northeastern part of forest Steppe of Ukraine SciensRise Biological Science. 2017. Vol 3(6). P. 27-33.

CONDITIONS FOR THE CREATION OF FOREST CULTURES IN THE TERRITORY OF THE NORTHEASTERN FOREST-STEP OF UKRAINE

Serhii Butenko
Doctor Phd, Lecturer of the Department, Sumy National Agrarian University, Ukraine
ORCID ID: 0000-0002-9925-3029

The exploitation of forest resources and scientifically based forestry management are inextricably linked with reforestation and afforestation. According to calculations, on our planet annually forests are cut down on an area of more than 10 million hectares. Even more significant areas of the world's forests are annually covered by fires. In conditions where opportunities for reforestation are possible, sufficiently high reforestation rates are created, as a rule, in a natural way to optimize the accounts of types of felling, methods of clearing felling sites, technology for forest work, as well as measures to promote natural reforestation. Protest, on large-scale fires, with white seed trees, as well as on disturbed lands, afforestation is possible only in a rapid way.

One of the most important tasks of the forestry sector of Ukraine is the timely and high-quality reproduction of forests, increasing their productivity and biological stability with the involvement of economically valuable species of woody plants and reducing the terms of growing operational forests. The creation of forest crops ensures the formation of stands of the desired composition, high productivity and stability. In addition, reforestation is a promising strategy for containing global warming, which is based on the ability to bind carbon dioxide, while simultaneously providing key ecosystem services, including clean air and water. However, the creation of sustainable forest crops can be ensured only if there is high-quality planting material and a correctly selected technology for creating crops. The solution to this issue is relevant and requires detailed study.

Based on the analysis of survival and conservation, as well as growth indicators of forest crops, develop proposals for improving artificial reforestation in the State Enterprise "Forests of Ukraine", a branch of the Sumy Forestry of the Nedryhaylivka Forestry.

The research was based on the method of trial plots (TP) and model trees. In addition, other proven methods used in silviculture, forest taxation and soil science were used during the research.

Modern Trends in Forest Regeneration

The goal of forest regeneration, as stated in current regulatory documents, is to revive depleted, dead and damaged stands by natural, artificial or combined means. Artificial reforestation is carried out in cases where natural reforestation is unattainable or impractical, or when it is necessary to introduce economically valuable tree species. In addition, it is used in areas where forest crops have died due to various factors.

Afforestation in forestry practice is understood as the process of planting trees on non-forest lands in order to expand the forest fund. This includes the creation of protective forest plantations on lands of various types: agricultural, industrial, transport, water fund, as well as on lands of industrial activity. The loss of forest areas on our planet is a cause for concern: according to estimates, 36 football fields disappear every minute. Deforestation is caused by a variety of factors, including fires, clearing for agriculture or urban development, and mining. Forests play a crucial role not only as habitats for diverse flora and fauna, but also as a vital resource for people around the world, providing timber, paper, food, and components for a variety of products such as medicines and cosmetics. Forests are also essential for the well-being of the planet, as they contribute to the water cycle, prevent soil erosion, and absorb significant amounts of carbon dioxide, mitigating the effects of climate change.

To combat deforestation, numerous organizations around the world are engaged in massive tree planting and forest ecosystem restoration. There is now a growing global movement and hype around tree planting, driven by a desire to achieve a variety of ambitious goals. These goals include restoring forest cover to mitigate climate change, as well as providing other environmental benefits such as soil stabilization, watershed protection, and wildlife habitat.

Notable initiatives of this movement include the World Economic Forum's One Trillion Trees Initiative, the Bonn Challenge, the UN Decade of Ecosystem Restoration, and the recently established US Interagency One Trillion Trees Council. Reforestation has the potential to sequester an average of 6 metric tons of CO_2 per hectare annually, but it is important to consider the other benefits of reforestation, such as cycling and evapotranspiration. The importance of reforestation cannot be overstated.

There is a consensus among researchers that artificial forest plantations are superior to natural ones in terms of productivity. Therefore, increasing the share of artificial reforestation and afforestation is considered a promising strategy for increasing forest productivity. Here are the advantages of artificial reforestation compared to natural.

Artificial reforestation and afforestation offer several advantages, including a higher growth rate of plantations at a young age and a faster rate of wood accumulation up to a certain age. In addition, they can reduce the period of plantation cultivation by 10-20 years and delay the onset of competition between trees until the crowns close.

The concentration of more trees in the central steps of the thickness also leads to weaker tree differentiation. In addition, artificial reforestation helps prevent unwanted species change and allows for the creation of plantations for different purposes. It also improves forest vegetation conditions by cultivating the soil and ensuring a uniform distribution of trees on the site. In addition, it accelerates the targeted selection of tree species and allows for the simultaneous settlement of the cultivated area. In addition, artificial afforestation makes it possible to grow plantations in areas where tree species did not previously exist or where natural sources of fertilization are absent. This method also accelerates the reclamation of disturbed lands and contributes to the formation of aesthetically attractive landscapes.

The creation of artificial plantations can be achieved by sowing or planting methods. Each approach has its own advantages and disadvantages when it comes to the creation of forest crops. However, experts widely accept that plantations created by planting demonstrate better characteristics. These include higher survival and conservation rates, faster growth, lower density and increased resistance to competition from undesirable species, undergrowth and depletion of the topsoil. Therefore, it can be concluded that forest crops established by planting prove to be more effective and efficient in the field of forestry, as confirmed by various sources.

The process of creating artificial plantations is associated with numerous difficulties. In particular, afforestation and reforestation by planting requires the use of high-quality planting material suitable for certain zones. For this, it is necessary to create seed storage facilities and create nurseries for growing uniform planting material. In addition, the implementation of a comprehensive set of agrotechnical and forestry measures is crucial for the successful cultivation and maturation of forest crops. As a rule, planting material is grown in forest nurseries takes about 2-3 years, which emphasizes the need for cultivation techniques that take into account regional natural and economic conditions. In addition, it is necessary to take effective measures to combat not only weeds, but also pests and diseases. Based on extensive forestry knowledge, it has been established that when restoring Scots pine, priority should be given to forest crops. However, some aspects of its cultivation, including the treatment of sandy soils, methods of mixing with other tree species, determining optimal density and placement of planting sites, continue to be the subject of debate.

Advantages and Disadvantages of Different Forest Crop Creation Technologies

A variety of alternative methods for establishing forest crops are currently available in different countries around the world. These methods include direct seeding, bare-root planting, and closed-root planting, including those made from biodegradable bio-pots. The advantages of direct seeding include the ability to quickly sow large areas, lower costs compared to planting seedlings, and the development of a well-structured root system in established crops. The positive side of seed sowing is its similarity to natural conditions, which leads to increased resilience of these plantations. In addition, from an economic point of view, this method is more advantageous, since it requires only one worker with a hoe or hand seeder, while two workers are required to plant seedlings. In addition, the cost of growing one seedling significantly exceeds the cost of the seeds.

On the other hand, there are several potential disadvantages of direct seeding. These include problems in obtaining sufficient quantities of viable seeds, lack of information on the most effective sowing methods, variations in the timing and duration of seed germination, and the risk of predation of seeds and seedlings by insects, birds and rodents. In addition, competition from existing vegetation, particularly grasses and shrubs, can be a significant obstacle.

An alternative approach is to use bare-root seedlings, which are dug up, stored and transported without any soil around them. Planting bare-root seedlings is a cost-effective and simple method, as this type of planting material has the property of adapting well to changing field conditions.

The success of artificial afforestation is greatly influenced by the caliber of planting material used to establish forest crops. This, in turn, depends on the size and proportions of the underground and above-ground components of the seedlings and saplings, as well as on the weight of physiologically active roots. To increase the mass of active roots, special methods of growing planting material have been developed when using seedlings or saplings with an open root system. In addition, measures have been taken for the safe transportation and storage of dug seedlings and saplings to prevent drying out.

To ensure the availability of first-class planting material in our country, an extensive system of forest nurseries has been created, both temporary and permanent, including basic ones, as well as greenhouses. The advantage of using greenhouses for growing planting material is that they contribute to the creation of ideal conditions for seed germination and seedling growth. Thanks to the use of a greenhouse, it becomes possible to sow seeds a month earlier compared to open ground conditions, as a result of which planting material is obtained in one year, which is comparable in size to standard two-year seedlings.

There were several noticeable disadvantages associated with the use of seedlings grown in forest nurseries for planting both in open ground and in greenhouses. The use of seedlings or young trees with an open root system greatly limited the timing of planting. Any delay in the planting process can lead to dehydration of the topsoil, which will eventually lead to the death of the newly planted vegetation or a significant decrease in survival rates. In addition, the root system of seedlings (or young trees) dries out during planting, especially in hot and windy weather, which leads to their premature death.

In other words, the main disadvantage associated with the use of bare-root planting material has been the limited timing of planting of forest crops, which is largely dependent on weather conditions. When it comes to large-scale artificial afforestation or reforestation projects, even with the use of mechanized planting technologies, significant problems have arisen in achieving optimal planting within the specified time frame.

In order to overcome the limitations associated with bare-root planting material, it is important to explore approaches to mitigate these limitations. In the 1960s, attempts were made to create a technology that would allow obtaining planting material from CRS. As a result, planting material from CRS was launched. This specific type of planting material included seedlings or saplings in which their root system was enclosed in the substrate. Undoubtedly, planting material from CRS had a number of noticeable advantages compared to material from ORS. It is noteworthy that it showed increased drought resistance. The presence of water supply in the substrate coma extended the duration during which the material could be stored and transported without the need for additional watering.

It is worth emphasizing that theoretically, planting material with a closed root system has the ability to withstand a long period without atmospheric moisture when planted in forestry areas. Therefore, more and more attention is paid to improving the technologies for obtaining planting material from CRS.

Such planting material has numerous advantages compared to conventional seedlings and saplings. In particular, seedlings with CRS better adapt to difficult forest conditions, demonstrate resilience during long-distance transportation and, most importantly, allow for a longer harvesting season. In addition, other benefits of using seedlings include a shortened growth period for large-scale projects.

The use of improved planting stock has been shown to increase the survival of some tree species, including Scots pine. This allows for successful establishment of forest crops in difficult vegetation conditions, such as rocky areas, quarries, and other damaged lands. With high survival rates of these forest crops, it becomes possible to reduce the number of plantings per unit of forestry area and optimize the use of selected seeds. The use of container seedlings for reforestation and land restoration offers a more consistent and uniform approach. By transplanting these seedlings, established forest crops can avoid early environmental and biological stress, which will ultimately lead to earlier maturity compared to bare-root or seed plants. It is important to emphasize that minimal post-planting depression promotes rapid growth of forest crops, thereby reducing the need for extensive agrotechnical care. The growing trend of using closed-root planting material in forestry is not accidental, as it has gained popularity both domestically and internationally.

The use of “container seedlings” from CRS in European countries, particularly in Finland, has made it possible to reduce planting costs and extend the planting season. However, this planting technique initially encountered problems. Some Scots pine (Pinus sylvestris) and lodgepole pine (Pinus contorta) seedlings suffered from severe root deformation, which led to impaired growth and reduced stand stability. Consequently, considerable efforts were made to improve container design and prevent root deformation. Various container designs were tested, such as containers with a downward slope to guide the roots, and containers treated with copper or open to the air so that the tips of the roots did not reach the edge of the container.

In the market of Northern European countries, container-grown seedlings occupy a significant share. However, bare-root seedlings have certain advantages, primarily their larger size and increased resistance to damage caused by the pine weevil (Hylobius abietis). As a result, bare-root seedlings continue to be widely used, especially in the southern regions.

In regions located in the northern hemisphere, where the land is fertile and rich in vegetation, there is a significant threat posed by the pine weevil and other destructive pests. However, when comparing seedlings grown with a closed root system (CRS) and seedlings grown with an open root system (VRS), it can be seen that the latter take longer to establish a strong connection between their roots and the soil, thus delaying the onset of water absorption. As a result, CRS seedlings often show greater height growth during the first and second years after planting than ORS seedlings. However, studies have shown that this height discrepancy becomes less pronounced 3-5 years after planting. The use of very small mini-seedlings, which has been tested in Finland, Sweden and Canada, represents another potential option for reducing the costs associated with seedlings and planting. These trials initially focused on Scots pine seedlings, but later in subsequent field experiments, Norway spruce seedlings were included. According to Johansson et al. (2007), if mini-seedlings successfully root, they show comparable or even better growth compared to larger seedlings. However, they are more susceptible to the conditions of their planting environment and require careful care. In addition, other researchers have found that mini-seedlings suffer less damage from pine weevils compared to one-year-old seedlings, possibly due to the release of limonene, a known repellent for these pests. The use of closed-root planting material in the cultivation of productive and resilient stands has been widely recognized in numerous publications. However, the production and transportation of seedlings for this method can be more expensive and complicated. In this regard, its implementation in Ukraine has not become widespread. On the contrary, other countries have been successfully using this technology for the past four decades. Currently, in Europe and the USA, approximately 90% of all seedlings are grown in CRS. Studies by foreign scientists have shown that in some cases, growing planting material from CRS can be more economically profitable compared to traditional open ground methods. The profitability of using this method depends on the amount of production and the specific area of forest vegetation. For example, in the southern regions of the

United States, growing planting material in containers is becoming increasingly profitable when the production volume reaches 2-6 million seedlings per year.

Therefore, the choice of planting system depends on many factors, such as the intended purpose of planting, the associated costs, the productivity of the crops grown and the economic value of the plantation.

Natural Conditions of The Study Area

Located on a vast expanse of the Earth's surface known as the East European Platform, Sumy Oblast is home to a unique geological feature. Underneath layers of sedimentary rocks 600 to 700 meters thick lies a solid Corinthian bedrock known as the crystalline basement. This geological formation is located in the Sumy district, not far from the city of Sumy.

The relief of the eastern part of Sumy Oblast consists mainly of spurs of the Central Russian Upland, which extend to the northeast of the region. As a result, the entire region slopes from northeast to southwest.

The average elevation in this area is about 200-220 m. The relief of this region is also influenced by surface rocks, in particular loess, which is a light brown porous carbonate rock. These loess deposits are easily eroded by water, leading to the formation of ravines and gullies. Thus, the territory of this region is quite fragmented, both flat areas and areas with erosion signs.

A very intricate network of spring beams can be found throughout the region. The eastern border of the region is part of the Central Upland, on which the noticeable Khotyn-Sumy Plateau stands out. Within the Sumy region, the Khotyn-Sumy Plateau reaches its highest points of 228 m in the upper reaches of the Loknya River and 224 m in the upper reaches of the Oleshnya River (located northeast of the village of Korchakivka). Descending to the southwest from these peaks, the plateau smoothly drops to 204 m in the watershed of the Sumka and Oleshnya rivers. In general, the plateau consists of an elevated plain crossed by rivers that flow radially outward. The Loknya, Snagost rivers and their left tributaries flow to the north, and the Kryga River to the west. The Oleshny River in the middle and lower reaches stretches to the south-southeast, and the Huyva River flows to the east along a beam-shaped valley. On the southern side, the plateau steeply descends to the Psel River valley, forming its right bank, dissected by deep branched beams. On the northern side, the plateau has a more gentle slope and is not so divided by beam-shaped river valleys. The valleys of these rivers and the watersheds between them create a slightly undulating relief. In the north, there are mainly sod-podzolic soils, and in the south - typical chernozems, including deep low-humus, medium and light loamy and leached medium-humus chernozems. Sod-meadow soils prevail in the floodplains of the rivers. Sumy region has an extensive river network, through the territory of which 1,543 rivers flow. All these rivers belong to the Dnieper basin and are mainly its left tributaries. The Great Desna River flows through the region for 37 km, and six medium-sized rivers flow through the territory of Sumy region.

The region boasts an impressive number of water bodies, including 25 large lakes, 2,191 smaller ponds and 43 reservoirs, which together contain a staggering volume of almost 223 million m^3 of water. Beneath the surface, the region's subsoil is rich in a variety of valuable minerals. Notably, it is rich in fuel and energy resources such as oil, natural gas and peat. In addition, non-metallic minerals such as phosphorites, rock salt, quartzites, chalk, marl, as well as raw materials for the production of bricks, building sand and stone are also found in significant quantities in the region.

The climate of the region is temperate continental. In 2023, the average temperature was 8 - 9°C, exceeding the annual average by 2-2.5°C. The peak air temperature of 35-35.5 °C occurred in the north of the region in July-August, and the coldest temperatures of 21-24 °C were recorded in January-February. The annual amount of precipitation was 476-659 mm, which was 74-109% of the average annual norm.

Reforestation and Afforestation

Forest management is a key function of a forestry enterprise, which includes the cultivation, restoration and protection of forests, as well as increasing their productivity and component quality. The economic activity of a forestry enterprise is aimed at the economical use of forest resources, improving the condition of forest plantations, developing recreational activities in forests, preserving and strengthening their sanitary, hygienic, aesthetic and protective functions.

Efforts are aimed at increasing forest productivity and improving the composition of forests by implementing forest restoration methods. This involves growing economically valuable tree species and implementing effective methods of forest management. In addition, measures are being taken to protect forests from fires, pests and diseases.

The primary task of the Nedryhaylivka Forestry Enterprise is the constant and purposeful creation of new forest plantations that exceed the area of the felled land. In addition, the farm seeks to preserve these stands, increase their productivity, ensure their rational use, while improving the useful qualities of forests and improving their ecological condition. In 2018, the SE "Nedryhayliv Forestry" carried out large-scale forestry work. During the spring and autumn seasons, forest restoration work was carried out on forest lands with a total area of 69.5 hectares. This includes:

61.5 hectares were allocated for planting and sowing of the forest, another 8.0 hectares were left for natural regeneration. In addition, 3.7 hectares were specially allocated for growing New Year's tree plantations (Fig. 1).

Fig. 1 *Areas of Picea tree plantations*

When reforestation is carried out in modern times, preference is given to the use of planting material with a closed root system. Using this method, it becomes advisable to create stands of trees that are both highly productive and biologically stable throughout the growing season.

The forest farm exceeded the planned harvest in 2019, collecting a significant amount of 22.0 kg of pine seeds and a significant 12 thousand kg. of oak acorns. This surplus is crucial for creating forest seed reserves, ensuring proper accounting for subsequent years with limited or no seed harvests.

To acquire high-quality seed material, the forest farm adheres to a certain set of measures, which includes the collection and processing of forest seeds.

• Quality confirmation in the process;
• Use of already established seeds in nurseries, greenhouses and containers;
• Transplanting seedlings to forest land for the cultivation of productive and environmentally sustainable plantations in the future. As of January 1, 2023, the permanent forest seed base of the forestry consists of certified areas with a total area of 54.9 hectares (forest seed plantations). Approximately 80 percent of the required seeds are obtained from these areas each year.

Fig. 2 *Plot with planting material Quercus robur L*

The forestry includes three nurseries with a total area of 3.5 ha. In addition, there are greenhouses with an area of 0.07 ha, which are responsible for growing approximately 600 thousand trees each year. The main focus of planting material is Scots pine - 300 thousand specimens and common oak - 190 thousand pcs. (Fig. 2.3.3).

Nurseries play a crucial role in the cultivation and sale of ornamental seedlings, meeting the requirements of landscape design projects. A significant number of 20 thousand seedlings, consisting of 56 different species, are grown each year to meet these landscaping needs. In addition, since 2018, the nursery has been operating a greenhouse with an area of 0.02 ha using mist irrigation technology.

Clearing of Felling Areas, Timber Harvesting

To improve the quality of forests, promote their well-being, and strengthen their protective properties, forestry activities such as maintenance felling, sanitary felling, and forest regeneration felling are carried out (Figure 3).

Fig. 3 *Wood harvesting process*

The main activity of the enterprise is the extraction of wood, both for direct use and for logging. In addition to timber harvesting, the enterprise is also engaged in wood processing.

Accurate and reliable information about forest resources is important for the modern economy. To ensure the accuracy and efficiency of forestry operations during forest felling, advanced technologies and equipment are used. These tools significantly simplify the management of forestry operations and increase their quality due to their convenient design and high level of accuracy.

The development and use of a functional and high-quality geographic information system requires the use of modern equipment with high accuracy. This equipment plays a crucial role in performing various cartographic tasks necessary for effective forestry management. These tasks include determining the current coordinates of specific points, plotting turning points and boundaries of forest plots, calculating distances in certain directions, measuring plot areas immediately after the survey, and accurately determining the location of objects or people relative to the forestry tablet on site.

For 1996-2005, the forestry received approval for the estimated volume of final felling of 13.2 thousand m3. Of these, hardwoods - 7.2 thousand m3, conifers - 2.8 thousand m3, softwoods - 3.2 thousand m3. Interestingly, the actual volume of felling per year averaged 98% of the estimated volume of felling for the entire inspection period.

The discrepancy between actual timber production in the commercial sector and forecasted logging indicators is minimal and ranges from 0% to 8% for individual tree species. All areas designated for primary logging have been successfully developed in accordance with the forest management project. This is due to the annual agreement on the allocation of priority logging, which takes place within the framework of the current forest management. The principle of uninterrupted and continuous forest use is reflected in the current estimated timber production and its actual implementation. Insufficient financial resources allocated between 1998 and 2003, combined with the lack of demand for harvested wood, are the main factors contributing to the noticeable discrepancies in the volumes of both clearing and thinning logging. The significant excess of through-cutting in terms of area can be explained by the change in the age composition of forests and the existing demand for wood products. In addition, the significant deviation in the yield of commercial timber during thinning and through-cutting logging can be explained by the large number of dead trees in oak stands.

The general condition of the stands, in which no maintenance fellings were carried out during the forest management year, with the exception of a small part of young trees under 20 years of age, was recognized as satisfactory. The quality of maintenance and selective sanitary fellings is also satisfactory. These measures played a significant role in improving the sanitary condition of the stands, which led to a decrease in the number of areas affected by forest diseases and pests. The enterprise carefully keeps records of forest pests and diseases, strictly adhering to sanitary regulations.

The main approach to timber harvesting is a mixed method, which combines basic and grassroots maintenance strategies. Wood obtained from maintenance and sanitary fellings is transferred to enterprises, local organizations and citizens for various purposes, including personal use and processing.

According to inspection reports, during the audit period, reforestation fellings were carried out on an area of 34.3 hectares. This led to the felling of a total stock of 6.8 thousand m3 in mature and mature stands, which lost their protective and other functions.

Key Performance Indicators

In terms of work volume, our company annually reforests an area of 74 hectares. In addition, we carry out logging operations, harvesting approximately 37.4 thousand cubic meters of wood. In addition, we process part of this wood at our own facilities, producing about 3.3 thousand cubic meters. In terms of sales volume, our revenue for 2020 amounted to 42,632.0 thousand UAH. To support these operations, we have a special team of 120 employees, each of whom receives an average monthly salary of 11,343.35 UAH.

There is a lower warehouse at the Southern Railway station, from which wood is exported. A fleet of 24 cars and 15 tractors is involved in this operation. The annual cargo turnover is 27.5 thousand m^3.

To meet the demand for decorative planting material, the forestry has expanded its focus to growing evergreen exotic seedlings in closed conditions. However, the forestry's primary task remains reforestation.

The importance of forestry in the regional economy cannot be overestimated, as it performs many roles, such as supplying wood for local needs and industry, serving as a source of nature protection and recreational activities through forest plantations, and also providing a variety of non-wood products.

Research Methodology

To fulfill the goal and objectives of the study, a work program was developed and implemented, which included the study of the scientific and departmental base for modern forestry production technologies.

Study the environmental factors present in a specific research site.

Our goal is to analyze the practical application of the technology and the number of Scots pine forests grown in the Nedryhaylivka forestry. We seek to assess the stability and preservation of forest plantations created by using bare-root Scots pine seedlings.

Using the results of the research, formulate recommendations aimed at activating the process of artificial reforestation in the Nedryhaylivka forestry.

The survey of forest crops was carried out using the test plot method. When creating all test plots, the instructions set out in GOST 56-69-83 were followed, namely, Experimental forest management areas.

The analysis of silvicultural and taxonomic characteristics of tree species in the composition of forest crops was carried out according to generally accepted methodologies in the field of forestry and forest taxation. This study was supported by the “bookmark method” and systematic recommendations. In addition, the current “Instructions for the design of forestry facilities” provided further justification for the study.

The assessment of the survival of various tree species was carried out in 1-5-year-old plantations created in the Nedryhaylivka forest farm. For this, the selected plots were delimited by rectangular test plots that corresponded to the age of the crops. Each plot was accurately measured using protractors and tape measures and secured at the corners with pegs. During the studies, the number of planting sites, the density of surviving plants, as well as the row spacing and planting interval were determined.

The survival rate of forest crops was assessed at different planting points (PP). Viability, which refers to the percentage of seedlings that successfully survive out of the total number planted during the first year, and survival, a similar measure taken one year after the establishment of the forest plantations, were determined.

Within the framework of mixed-age forest plantations created by manual planting with an open root system, planting sites were selected. These areas had similar relief, forest vegetation conditions, and a consistent history of forest plantation establishment at the time of establishment of the planting points (PPs). To assess the viability of each PP, all surviving Scots pine specimens were measured, including their height, lateral shoot length, number of needles per 5 cm of the axial shoot, and growth over the previous year. A total of 545 measurements were documented. Additionally, 5-10 dead Scots pine specimens were excavated from each PP to determine the causes of their death, if possible, to be found on site.

To identify specific conditions of forest vegetation cover and classify forest type, scientists used the established methodology of typological research. Information on the unique characteristics of forest vegetation conditions, methods of creating forest crops and historical prerequisites for their creation were obtained from various silvicultural projects.

The materials of experimental studies were subjected to statistical processing using methods of variational statistics and the Microsoft software package.

Reforestation in Forestry

The forest restoration process in the forest farm has some unique aspects. To facilitate this process, temporary nurseries with an area of 0.56 ha were created, as well as seed plantations with an area of 3.0 ha, intended for growing Scots pine. In addition, a greenhouse with a total area of 0.13 ha is used to grow approximately 1.0 million seedlings each year.

The current need for planting material is sufficiently met by the farm's existing nurseries. In addition, forest schools bring in additional planting material to supplement forest crops. For the effective implementation of the farm's reforestation work over the past two years, an average of 405 kg of seeds was required. For this purpose, these seeds must be collected.

Within the forest farm, the cultivation process takes place in plots. To ensure high-quality planting material with the necessary genetic properties, a specialized forest seed repository has been created in the specialized forest farm. According to the results of the 2022 forest management, the Nedryhaylivka Forestry Enterprise has set the task of restoring forests on a total area of 2,866 hectares (according to Table 3.1.1). The reforestation strategy has designated 81.7% of this area for the creation of forest crops, and the remaining 18.3% is allocated for natural regeneration.

According to the project, Scots pine is the dominant species in forest formation, accounting for 92.7% of newly created plantations. Black alder is in second place, which regenerates naturally - 6.5%. The forest enterprise allocates forest areas for natural regeneration, primarily in forest types B3DS, B4DS, which include Scots pine, as well as in C2GDS, which includes downy birch, and in C3GSD, which includes common oak. The forest enterprise provides for afforestation of 24.5 hectares. Among this area, 56.3% is allocated for artificial creation, and the remaining 43.7% is allocated for natural regeneration in forest areas. The dominant species responsible for forest formation is Scots pine.

According to the results of the survey of open areas, 39.7% fall into the 3rd quality class, 37.2% into the 2nd quality class and only 23.1% into the first quality class.

In the forest farm, forest regeneration measures are carried out according to a carefully developed strategy. The development of forest crops takes into account various elements, including the existence of natural regrowth, distinctive features of the forest and the characteristics of the forest area. Nevertheless, it is important to recognize that the degree of mechanization of such labor-intensive activities as planting and growing crops remains relatively minimal.

Table 1. Projected volumes of reforestation activities on forest areas and fellings not covered with forest vegetation in the revision period, area, hectares

Breeds designed for restoration	Forest area categories			Total
	Not covered with forest vegetation	Logging sites of the revision period		
		Main use	Other logging	
Forest crops				
Pinus sylvestris L	364,6	1972,0		2336,6
Quercus robur L	4,0	2,0		6,0
Total:	**368,6**	**1974,0**		**2342,6**
Natural renewal				
Pinus sylvestris L	316,1	5,0		321,1
Quercus robur L	0,5			0,5
Betula pendula	2,0	14,0		16,0
Alnus glutinosa L	39,8	146,0		185,8
Total:	**358,4**	**165,0**		**523,4**
Total by household:				
Pinus sylvestris L	680,7	1977,0		2657,7
Quercus robur L	4,5	2,0		6,5
Betula pendula	2,0	14,0		16,0
Alnus glutinosa L	39,8	146,0		185,8
Total:	**727,0**	**2139,0**		**2866,0**

The farm uses a traditional approach to planting, using pre-prepared grooves and strips. To prepare the soil for sowing, mechanized methods are used, which include the formation of furrows at a distance of 2.5-3 m from each other with a depth of 15-20 cm. This task is performed using a combined tractor MTZ-82 and a combined forest plow (PKL-70). The actual planting of the forest is carried out manually by individuals using a Kolesov sword.

The silvicultural fund consists mainly of lands that are not forested, as well as areas where sanitary and main use fellings were carried out during the audit period. In addition, it includes low-productive and low-value plantations that are included in the reconstruction fund. The determination of the forestry fund in felling areas in the audit period is based on economic considerations and takes into account the projected fellings in the future audit period. When developing methods for reforestation and afforestation, the direction and success of natural regeneration in different types of forests and categories of land are taken into account. The average regeneration period for areas designated for natural regeneration is usually 2-3 years. In 2021, significant work was carried out to restore forests with a total area of 522 hectares. It should be noted that forest crops were created on a huge area of 470 hectares, which is almost twice as much as last year's - 290 hectares. A feature of the forestry work this year is that 98.7% (464 ha) of newly created Scots pine plantations were established in areas previously affected by intense fires last year. The dominant species responsible for the formation of these forests is the stable Scots pine, which currently occupies a large area of

469 ha. In addition, a 52 ha area has been allocated for natural regeneration, of which 32 ha are for pine growth, 12 ha for flowering downy birch, and 8 ha are thoughtfully planted with alder.

Scots pine forest plantations can be created both in spring and autumn. However, the number of forest crops planted in autumn is minimal, and their chances of survival are also low — from 44% to 81%. Therefore, a larger proportion of these crops require fertilizing compared to those planted in spring. As a result, spring plantings demonstrate better survival, require fewer additives and achieve timely closure. Therefore, in the territory of the Ovrutskyi special forestry enterprise, it is customary to plant pine in the spring, which accounts for approximately 96% to 100% of all established crops. The best time for planting is early spring, using seedlings aged 1 to 2 years. Approximately 4 to 8 thousand pine seedlings are planted per hectare.

The most common forest-vegetation conditions for growing crops are B2 (52%), A2 (29%), Bz (19%). Soil care for forest crops occurs during the first five years of growth and consists of destroying weeds and loosening the rows of forest crops. The frequency of maintenance is as follows: five times in the first year, four times in the second year, three times in the third year, twice in the fourth year and once in the fifth year. 100% of soil care work in forest plantations is done manually.

The duration during which forest plantations reach full closure and transition to forest areas with established vegetation depends on the specific forest type and dominant species. On average, it takes about 6 years for Scots pine, and 7 years for Scots oak. The technical assessment of Scots pine plantations shows that 86.2% (400 ha) are classified as "excellent" and 13.8% (64 ha) are classified as "good". These results demonstrate the effectiveness of artificial reforestation measures to achieve high productivity.

In order to assess the survival and growth indicators of pine forest plantations, regular bonitization is carried out.

Assessment of Survival and Growth Indicators of Scots Pine Forest Crops

The work assessed the survival and growth indicators of Scots pine forest plantations established in forestry from 2019 to 2023 (Table 2). All surveyed plantations were created on log cabins. The dominant species in all experimental plots was Scots pine, although mixed plantations with birch as an additional component were found in some trial plots. The dominant forms of forest vegetation were fresh and moist soils. The standard planting location, which is usually used, is 3.0 x 0.7. After the introduction of mechanized tillage, plantations ceased to be created manually.

Table 2. Forest crops used for analysis

Quarter	Board	Area, hectares	Main breeds	TFC	Forest area category	Placing	Mixing scheme
1	9(1)	0,9	Сз	B2	Framework	2,5x0,7	3rSz2Bp+Yabl
2	17	2,0	Сз	B3	Framework	3x0,7	10pСз
2	5	1,5	Сз	B2	Framework	3x0,7	10pСз
5	28	1,5	Сз	A2	Framework	3x0,7	10pСз
22	6	1,4	Сз	B3	Framework	3x0,7	3rSz2Bp

The results of the research indicate a significant survival and preservation of forest crops, as evidenced by the data presented in Table 3. In addition, the preservation of crops in the study areas aged from one to three years exceeded the established standard. In particular, the level of preservation of one-year and two-year crops reached 90%, while three-year crops were maintained at a level of 83% in the specified study region.

The preservation of crops for one and two years reached 90%, while three-year crops were maintained at a level of 83% in the specified study region (Table 3).

Table 3. Survival and survival of Scots pine forest crops in trial plots

Quarter	Board	№ TA	Year of planting	Density, thousand pcs./ha	The age of creation of f. cultures	Survival (preservability)
1	9(1)	5	2019	4,8	5	84,2
2	17	4	2020	4,8	4	84,8
2	5	3	2021	4,8	3	85,6
5	28	2	2022	4,8	2	88,1
22	6	1	2023	4,8	1	91,1

The reason for the impressive survival rate can be explained by the timely establishment of these forest crops and the use of state-of-the-art technologies. Interestingly, there was no noticeable difference in viability between pure and mixed crops.

The year of planting has a constant effect on the stability of crops. The survival of crops worsens with each passing year. Among the trial plots, the most successful survival rate – 91.1% – was in Scots pine plantations planted in the spring of 2020 in trial plot No. 1. On the other hand, the least was in the 2019 plantations on FR5 – 84.2%.

The successful establishment and initial growth of forest crops largely depends on two factors: the depth at which the seedlings are planted in the soil and the location of their roots. The greatest decrease in seedling survival occurs during the first year after planting. Analysis of dead seedlings showed that the main causes of death of seedlings with a bare root system are dehydration, which accounts for 27.7% of cases, and predation by wild animals.

In the trial plots of forest crops, we measured their condition, paying special attention to the height of the shoots (or the length of the axial shoot) and the length of the lateral shoots. These measurements serve as a tax indicator, which is believed to be very characteristic of the overall condition of the crop. After analyzing the data, we found that the main reasons for the poor condition of the crops are as follows: 14.1% of the crops had roots covered with sand during planting, 10.2% suffered from bending of the roots during planting, 8.2% had insufficient root pressure. taproot, and 5.9% were affected by other factors. These findings highlight the importance of proper planting techniques and rootstock care to ensure the viability and growth of forest crops. In addition, in Scots pine crops, stand growth over the previous year was assessed and the number of needles per 5 cm of vertical branch was recorded.

Table 4. Statistical indicators of the length of axial (central) and lateral shoots of Scots pine in forest crops, cm

No. In Order	Year of creation	Sprout	Maximum valueue	Minimum value	Average value	CV, %
1	2023	Axial	25,2	8,1	14,9±0,26	23,5
		Side	7,8	3,7	5,60±0,68	32,1
2	2022	Axial	72,8	25,6	40,5±0,45	66,4
		Side	25,0	6,9	8,6±0,31	36,2
3	2021	Axial	95,1	33,2	70,1±0,17	54,2
		Side	33,7	12,3	18,6±0,47	38,9
4	2020	Axial	100,0	40,2	95,6±0,23	49,3
		Side	40,1	13,2	23,6±0,42	18,9
5	2019	Axial	195,0	78,5	155±0,65	73,5
		Side	56,2	32,1	45,2±0,45	23,5

Scots pine trees in the 2023 harvest ranged in height from 8.1 to 25.2 cm with an average height of 14.9 cm. In addition, lateral shoots had an average length of 5.6 cm. It is worth noting that the coefficient of variation is higher for lateral shoot length compared to seedling height (Table 4).

In 2022, new two-year crops were established, demonstrating a height range from 25.6 cm to 72.8 cm. The average recorded height was 40.5 ± 0.45 cm. In these crops, lateral shoots of pine varied in length from 6.9 cm to 25.0 cm. The average length of these shoots was 8.6 ± 0.31 cm. It should be noted that the coefficient of variation of height exceeded the coefficient of variation of lateral shoot length.

In experimental area No. 3, pine crops had a height range from 33.2 cm to 95.1 cm with an average height of 70.1±0.17 cm. In addition, lateral shoots had an average length of 18.6±0.47 cm.

For 4-year-old crops, the typical length of the main shoot (PP4) is 95.6±0.23 cm, and lateral shoots are about 23.6±0.42 cm. It is worth noting that the coefficient of variation is higher for crop height and reaches 49.3%.

In the 2019 plants, pine trees had a height range from 78.5 to 195 cm with an average measurement of 155±0.65 cm. Lateral shoots had a length of 32.1 to 56.2 cm with an average value of 45.2±0.45 cm.

In almost all test plots, except for PP1, the coefficient of variation of the height of axial shoots is higher than that of lateral ones. This indicates that the length of axial shoots in forest crops has a wider range of variation and is more responsive to environmental changes. It is this parameter that allows us to more fully reflect the state of cultivated forest crops.

The natural growth of Scots pine directly correlates with the age of the stands. By selecting the studied samples from comparable conditions, we can establish consistent patterns of height fluctuations over time (see Table 5).

Table 5. Statistical indicators of growth of tree species in forest crops in height over the last year, cm

Indicators	TA 1	TA 2	TA 2	TA 3	TA 4
Maximum valueue	9	40	65	50	80
Minimum value	3	9	15	20	30
Average value	5,9±0,22	20,4±0,36	35,9±0,71	41,0±0,11	54,1±0,01
Coefficient of variation, %	22,1	36,4	26,2	17,8	22,2
Accuracy of the experiment, %	3,7±0,45	2,0±0,45	2,5±0,12	2,8±0,32	2,5±0,21

The analysis showed that the correlation between height and planting by year can be accurately represented by a power function (Y2=0.99), with the equation in = 14.9x1.4102.. The most significant increase occurred between the fourth and fifth years.

Over time, since the establishment of pine plantations, the annual height increase showed a tendency to increase in the experimental plots.

It is noteworthy that the experimental plot No. 4 showed a larger annual increase, while the experimental plot No. 1 showed the smallest. It is worth noting that the experiment conducted in PP1 demonstrated the highest level of accuracy (3.7±0.45), while 11112 gave the lowest (2.0±0.45). The coefficients of variation of growth increment had relatively low values (from 17.8% to 36.4%), indicating a consistent trend within each trial area (corresponding to a certain age of the stands).

Conclusions

As a result of a thorough analysis of the practice of reforestation and the technology of creating forest crops used in the economy, as well as the study of the growth and condition of crops on the forestry trial areas, it was established that 81.7% of the reforested area of reforestation areas is intended for forest crops, and the remaining 18.3% is for natural regeneration. The majority of the created plantations belong to the second quality class - 54% of the total.

Forestry deserves praise for timely and high-quality reforestation, which contributes to the sustainable and efficient use of forest resources.

In the Nedryhaylivka forestry, traditional planting technology is used, which involves the early preparation of furrows and strips. Mechanized soil preparation is carried out with a combined forest plow (PKL-70) attached to an MTZ-82 tractor, creating furrows 15-20 cm deep with an interval of 2.5 and 3 m. The actual planting of the forest is carried out manually using a Kolesov sword.

The results of the study show that forest crops in all five experimental plots demonstrated excellent survival and preservation rates, ranging from 84.2% to 91.1%. This exceptional level of survival can be explained by careful adherence to optimal timing and advanced technologies in the creation of these forest crops.

In almost all trial plots, except for PP1, the coefficient of variation of the height of axial shoots is higher than that of lateral ones. This indicates that the length of axial shoots in forest crops has a wider range of variation and is more responsive to environmental changes. It is this parameter that allows us to more fully reflect the state of the forest crops being grown.

The natural growth of Scots pine directly depends on the age of the stands, in particular in terms of height. Extensive research has shown that

the most accurate reflection of the relationship between years of growth and growth occurs through the use of a power function.

The height growth of pine stands in the experimental plots showed a positive correlation with the length of time since their creation. In the experimental plot No. 4, a greater annual growth was observed, and in the experimental plot No. 1 - the smallest.

REFERENCES

1. Bykov M.K., Matveev M.S., (1960) Forest cultures. Results of scientific research on forest cultures in the Boyarsk experimental forestry. *K.: Publishing house of the Ukrainian Academy of Forestry and Forestry*, pp. 104 - 112.
2. Vedmid M.M., Lyalin O.I. (2009), Survival and growth of Scots pine cultures created by planting material with a closed root system. *Forestry and agroforestry: Collection of scientific works. Kharkiv: UkrNDILGA*, Issue 116. P. 146-152.
3. Vakulyuk P.G., Samoplavsky V.I., (1998) Reforestation in the plain regions of Ukraine. *Fastiv: Polifast,* 508 p.
4. Vakulyuk P.G., Samoplavsky V.I., (2006) Reforestation and afforestation in Ukraine. *Kharkiv: Prabor,* 384 p.
5. Gordienko M.I. et al., (1995) Scots pine, its features, establishment of cultures, productivity. *Kyiv: Lybid*, 224 p.
6. Gordienko M.I., Guz M.M., Debrynyuk Yu.M., (2005) Maurer V.M. Forest cultures. *Lviv: Kamula*, 608 p.
7. Gordienko M.I., Koretsky G.S., Maurer V.M. (1995) Forest cultures. *Kyiv: Silgosposvita Publishing House*, 328 p.
8. Gordienko M.I., Shlapak V.P., Goychuk A.F. et al., (2002) Cultures of Scots pine in Ukraine. *Kyiv: Urozhay*, 872 p.
9. Guz M.M., (1996) Root systems of tree species of the Right-bank forest-steppe of Ukraine. Monograph. K.: VK "Yasmina", 145 p.
10. Gordienko M. I., Guz M. M., Debrynyuk Yu. M., Maurer V. M., (2005) Forest cultures. *Lviv: Kamula*, 608 p.
11. Grom M. M., (2005) Forest taxation: a manual for students of higher education. Lviv: UkrDLTU, 352 p.
12. Debrynyuk Yu. M., (1993) Forest cultures of the plain part of the western region of Ukraine: *ed. Yu. M. Debrynyuk, I. I. Myakush. Lviv: Svit*, 296 p.
13. Debrynyuk Yu. M., Kalinin M. I., (1991) Optimization of mixing schemes when growing high-yielding cultures of common oak with the participation of coniferous species. *Kharkiv: UkrNDILGA*, 56 p.
14. Debrynyuk Yu. M., Kalinin M. I., (1998) Guz M. M., Shablii I. V. Forest seed production. (1998) *Lviv: Svit*, 432 p.
15. Debrynyuk Yu. M., Kalinin M. I., Oprysko M. V., (1995). Collection, processing and preparation of seeds for sowing of the main species of trees and shrubs growing in Ukraine. *Lviv: UkrDLTU*, 156 p.

16. Instructions for design, technical acceptance, accounting and quality assessment of silvicultural facilities / Approved by order of the State Forestry Committee of Ukraine dated August 19, (2010) No. 260. Kyiv: Derzhkomlishosp of Ukraine, P.74
17. Forestry of Ukraine. State Agency of Forest Resources of Ukraine. *Kyiv: Ukrliskonsalting*, (2013). 20 p.
18. Restoration of pine plantations by sowing and seeds on sites (nests). Results of scientific research on forest cultures in the Boyarsk Experimental Forestry Farm. *K.: Publishing House of the Ukrainian Academy of Forestry and Forestry*, (1960). p.134.
19. Forest taxonomy handbook / Girs O.A., Manita O.G., Myronyuk V.V. et al. *K.: Vinichenko Publishing House*, (2013). 496 p.
20. Ostapenko B.F., Tkach V.P., (2002) Forest typology: a teaching manual. *Kharkiv: Kharkiv Publishing House. Dokuchaev State Agrarian University*, 204 p.
21. Ostapchuk O. S., Oleksiychenko N. O., Sovakov O. V., (2013) The influence of the method of creating cultures on the growth and development of common oak (Oxycerium hortifolium L.). Scientific Bulletin of the National University of Life Resources and Environmental Management of Ukraine. *Ser.: Forestry and ornamental gardening*. Issue 187(3). P. 277-283.
22. On approval of the Rules for forest regeneration: Resolution of the Cabinet of Ministers of Ukraine dated 1.03.07. Central Committee: https://zakon.rada.gov.Ua/laws/show/303-2007-%D0%BF#Text
23. Redko G. I., Rodin A. R., Treshchevskiy I. V. (1980) Forest cultures. M.: Lesnaya prom-st, 368 p.
24. Rodin A. R., Shapkin O. M., (1972) Survival and growth of cultures created with large-sized planting material. *Forestry*. No. 9. P. 29.
25. Soyuk O. A., (2020) Restoration of Scots pine cultures under the conditions of the Prilutsk forestry of the Ovrutsk Forestry Enterprise. *Forest, science, youth: collection of materials of the VIII All-Ukrainian scientific and practical conference* (November 24, 2020). *Zhytomyr: University of Polesie*, pp. 150-151.
26. Types of forest crops by forest vegetation zones (2010) (Polissya and Forest-steppe, Steppe, Carpathians, Crimea). *Kyiv: Ukrainian State Project Forest Management Production Association*, 63 p.
27. Aronson J., Goodwin N., Orlando L., Eisenberg C., Cross A. T., (2020) A world of possibilities: six restoration strategies to support the United Nation's Decade on Ecosystem Restoration. *Restor. Ecol.* 2020. 28, 730-736. doi: 10.1111/rec.13170
28. Bala, G., Caldeira, K., Wickett, M., Phillips, T. J., Lobell, D. B., Delire, C., et al., (2007). Combined climate and carbon-cycle effects of large-scale deforestation. Proc. Natl. Acad. Sci. U.S.A. 104, 6550-6555. doi: 10.1073/pnas.0608998104.
29. Bastin, J.-F., Finegold, Y., Garcia, C., Mollicone, D., Rezende, M., Routh, D., et al., (2019). The global tree restoration potential. Science 365, 76-79. doi: 10.1126/science.aax0848.
30. Bengston D. N., Fan D. P., Celarier D. N., (1999) A new approach to monitoring the social environment for natural resource management and policy: the case of US national forest benefits and values. *J. Environ. Manage.* 56, 181-193. doi: 10.1006/jema.1999.0278.
31. Bonilla-Moheno M., Holl K. D., (2010) Direct seeding to restore tropical mature-forest species in areas of slash-and-burn agriculture. *Restoration Ecology*. 18(S2). 438445.
32. Cook-Patton, S. C., Gopalakrishna, T., Daigneault, A., Leavitt, S. M., Platt, J., Scull, S. M., et al., (2020). Lower cost and more feasible options to restore forest cover in the contiguous United States for climate mitigation. *One Earth.* Vol. 3. P. 739-752. doi: 10.1016/j.oneear.11.013.
33. Danielsson M., Kannaste A., Lindstrom A., Hellqvist C., Stattin E., Langstrom B., Borg-Karlsson A.-K., (2008) Mini-seedlings of Picea abies are less attacked by Hylobius abietis than conventional ones: Is plant chemistry the explanation? *Scandinavian Journal of Forestry Research*. Vol. 23. P. 299-306.
34. Domke, G. M., Oswalt, S. N., Walters, B. F., and Morin, R. S., (2020). Tree planting has the potential to increase carbon sequestration capacity of forests in the United States. *Proc. Natl. Acad. Sci. U.S.A.* 117, 24649-24651. doi: 10.1073/pnas.2010840117.
35. Federal Register, (2020). Establishing the one trillion trees interagency council (Executive Order 13955). Off. Fed. Regist. 85, 65643-65645.
36. Gray LK, Hamann A., (2011) Strategies for Reforestation under Uncertain Future Climates: Guidelines for Alberta, Canada. *PLOS ONE* 6(8). e22977. https://doi.org/10.1371/journal.pone.0022977.
37. Griscom, B. W., Adams, J., Ellis, P. W., Houghton, R. A., Lomax, G., Miteva, D. A., et al., (2017). Natural climate solutions. *Proc. Natl. Acad. Sci.* U.S.A. 114, 11645-11650. doi: 10.1073/pnas.1710465114.
38. Holl K. D., (2020) Brancalion P. H. S. Tree planting is not a simple solution. *Science*. Vol. 368. P. 580-581. doi: 10.1126/science.aba8232.
39. Johansson K., Nilsson U., (2007) Allen H. L. Interactions between soil scarification and Norway spruce seedling types. *New Forests*. Vol. 33. P. 13-27.
40. Li G.L., Zhu Y., Liu Y., Jiang L., Shi W., Liu J., Wang J., Cheng Z., (2011) Effect of nursery nitrogen application of bare-root Larix olgensis seedlings on growth, nitrogen uptake and initial field performance. *Journal of Environmental Biology.* 34 7985.

41. Lindstrom A., Hellqvist C., (2005) Stattin E. Mini seedlings—A new forest regeneration system J. S. Colombo The Thin Green Line—A symposium on the state- of-the-art in reforestation—Proceedings Forest Research Information Paper. 2005. No. 160. P. 59 61 Sault Ste Marie, ON, Canada.
42. McDonald, T., Jonson, J., and Dixon, K. W., (2016). National standards for the practice of ecological restoration in Australia. *Restor. Ecol.* 24, S1-S32. doi: 10.1111/rec.12359.
43. Neary D. G., Ice G. G., Jackson C. R., (2009) Linkages between forest soils and water quality and quantity. *For. Ecol. Manag.* Vol. 258. P. 2269-2281. doi: 10.1016/j.foreco.2009.05.027.
44. Nilsson U., Orlander G., (1999) Vegetation management on grass-dominated clearcuts planted with Norway spruce in southern Sweden. *Canadian Journal of Forest Research.*. 29. P. 1015-1026.
45. Nilsson U., Luoranen J., Kolstrom T., Orlander G., Puttonen P., (2010) Reforestation with planting in northern Europe, *Scandinavian Journal of Forest Research.* Vol. 25:4. P. 283-294, DOI: 10.1080/02827581.2010.498384
46. Parviainen J. 1976 Mannyn eri taimilajien juuriston alkukehitys [Initial development of root systems of various types of nursery stock for Scots pine] *Folia Forestalia.* 268.
47. Rune, G., (2003). Instability in plantations of container grown Scots pine and consequences on stem form and wood properties. Swedish University of Agricultural Sciences. *Acta Universitatis Agriculturae Sueciae. Silvestria,* Vol. 281. P. 1-35.
48. Suita E., Sudrajat D.J., Nurhasybi A., (2018) Pertumbuhan bibit sengon merah (Albizia chinensis (Osbeck) Merr.) pada media semai cetak dan perbandingannya dengan bibit polibag. *Jurnal Penelitian Kehutanan Wallacea.* 7(2). 141-149.
49. Verdone, M., and Seidl, A. (2017). Time, space, place, and the Bonn Challenge global forest restoration target. *Restor. Ecol.* 25, 903-911. doi: 10.1111/rec.12512
50. The White House (2016). *United States Mid-Century Strategy for Deep Decarbonization.* Washington, DC, 111.

CURRENT TRENDS IN THE USE OF ARTIFICIAL INTELLIGENCE (AI) FOR COMPUTER-BASED DESIGN OF GARDEN AND PARK OBJECTS

Viunenko Oleksandr
Ph.D. in Economic Sciences, Associate Professor, Sumy National Agrarian University, Ukraine
ORCID ID: 0000-0002-8835-0704

Current Trends in The Use of AI For Computer-Aided Design of Gardens and Parks

Artificial intelligence is radically changing the approach to the design and management of landscape facilities. Modern AI technologies offer innovative solutions for creating efficient and aesthetically appealing green spaces.

Key areas of application of AI in landscape design:

- Analysis of geographical and climatic data.
- Optimization of spatial planning.
- Automation of care processes.
- Creating 3D models.
- Forecasting development trends.

Due to meticulous analysis of vast data arrays, artificial intelligence ensures a considerable acceleration of the design process, which allows for making genuinely optimal and well-reasoned decisions. AI systems can take into account hundreds of parameters, from soil type to local climate.

Advantages of using AI in landscape design:

- *Improving design efficiency*
- Reduction of development time.
- Cost reduction.
- Improving design quality.
- *Resource optimization*
- Rational use of water.
- Energy efficiency.
- Optimal selection of materials.
- *Environmental sustainability*
- Reducing environmental impact
- Supporting biodiversity.
- Adaptation to climate change.

AI is actively used to create "smart gardens", where automation systems control watering, lighting and nutrient application. The application of machine learning technologies opens up opportunities for the accurate prediction of diverse plant needs, including water, nutrients, and lighting, and allows for the optimization of their care strategies based on the data obtained. "Artificial intelligence is not a replacement for human creativity, but a powerful tool for enhancing it in landscape design". In general, there are several features of the use of AI in landscape design:

1. Intelligent mechanisms are shaping a new era of landscape design.

In the context of big data processing, artificial intelligence demonstrates impressive capabilities in processing colossal volumes of information, which encompasses diverse geographic parameters, key climate features, important environmental factors, as well as a broad spectrum of other variable data. This allows designers to make decisions based on deep analysis, relying on complex databases.

Visual image recognition. Using deep learning technologies, AI can analyze images and video, helping landscape designers assess existing green spaces in more detail. This allows for more accurate and informed decisions about plant placement, zoning, and ecological adaptation of the environment.

Optimization of spatial solutions. The use of optimization algorithms makes it possible to use the territory as efficiently as possible, ensuring the harmonious coexistence of natural and artificial elements, such as trees, paths, recreation areas, etc.

Careful plant selection with detailed consideration of environmental features. AI analyzes climatic and soil conditions, allowing you to select the most adapted plant species that will ensure the sustainability and biodiversity of the landscape.

Economical use of resources. Through conducting a thorough and comprehensive analysis of data on water, energy, and material consumption, artificial intelligence contributes to achieving a significant reduction in operational costs and tangibly reducing the negative impact on the environment.

2. Benefits of integrating AI into landscape design.

Reduction of time and financial costs. Thanks to fast data processing, artificial intelligence allows you to reduce the laboriousness of the design process and significantly save the budget.

With the aim of consistently improving the quality of various projects, artificial intelligence effectively analyzes colossal volumes of diverse information, providing developers with the opportunity to make informed decisions based on objective data, which, as a consequence, leads to a significant increase in the quality of projects being implemented.

Enhancing creative potential. While artificial intelligence cannot completely replace human creativity, it significantly expands its boundaries, offering innovative ideas and unconventional solutions.

3. Smart Gardens: Synthesis of Nature and Advanced Technology.

Implementation of automated care: Artificial intelligence is actively being integrated into advanced smart garden systems, carrying out comprehensive control of watering, providing plants with essential nutrients, and even offering them protection from pests, creating optimal conditions for their growth and development.

Monitoring and analysis of the condition of green spaces. Smart systems controlled by artificial intelligence monitor plant health and timely notify about the need for intervention.

Rationalization of resource use. By analyzing environmental parameters, artificial intelligence helps to use water, light, and fertilizers more efficiently, contributing to sustainable development.

4. Considering the key role of artificial intelligence and the future prospects for the development of landscape design.

Trend analysis and forecasting. AI analyzes previous projects and consumer preferences, identifying new trends and predicting future directions for landscape architecture.

Creating interactive 3D models. Thanks to the utilization of advanced neural networks, contemporary designers gain the ability to create exceptionally realistic photorealistic models, which provides them with a valuable tool for pre-evaluating the final appearance of the project being developed and making necessary adjustments at the initial stages.

5. Challenges in integrating artificial intelligence.

The need for retraining specialists. To ensure the most effective application of artificial intelligence, there is a primary necessity for training highly qualified specialists capable of harmoniously combining in-depth knowledge in the field of landscape design with advanced digital technologies.

Data security and confidentiality. Processing large amounts of information requires the implementation of strict security standards to avoid risks of data leakage.

Harmonizing human-machine interaction. Effective collaboration between designers and AI requires clear synchronization of processes so that technology becomes an assistant, not a replacement, for human talent.

Innovative areas of development:

- Biophilic design with the integration of natural elements.
- Vertical gardening for efficient use of space.
- Smart plant health monitoring systems.
- Automated solutions for garden care.

Forecasts for the 2030s predict further development of AI technologies in horticulture:

- Regenerative gardening.
- Climate-adaptive solutions.

Through advanced research and technology, AI overcomes the limitations of traditional approaches, increasing the accuracy and efficiency of decision-making. The designer's artistic vision is based on his life experience, worldview, personal qualities and creative achievements. Cultural context has always played an important role in art, but today the amount of information available to humans is significantly inferior to the capabilities of computer systems.

Modern expert systems simulate the thinking process of specialists, analyzing complex issues and suggesting optimal solutions, and the use of artificial intelligence technologies contributes to increasing accuracy in the design process, which allows designers to quickly adapt their ideas to specific conditions. In addition, modern algorithms can imitate human emotions, which makes the process of creating a harmonious landscape more intuitive.

AI in landscape analysis and planning.

One of the key areas of AI application in landscape design is analysis and planning. Thanks to machine learning algorithms, designers can accurately process data about the environment, including relief, soil composition, climatic features and vegetation types. This helps to create informed solutions that meet the specific needs of the territory.

Additionally, AI algorithms can predict the long-term impacts of design decisions by analyzing aspects such as water balance, biodiversity, and carbon footprint, allowing designers to create sustainable and environmentally efficient landscapes.

Increasing creativity and innovation.

AI does not replace human creativity, but rather augments it. Generative algorithms can suggest multiple design options based on given criteria, allowing designers to experiment with new concepts. Modern artificial intelligence platforms, among other features, provide comprehensive support for innovative virtual reality (VR) and augmented reality (AR) tools, which unlocks a unique opportunity for clients to visually review developed projects and actively interact with them in a fully digital environment directly at the design stage.

Automated 3D design.

Modern technologies of artificial intelligence, 3D modeling, and visualization have gained widespread application in diverse industries and fields of activity, including, in particular, such an important field as landscape design. The application of computer-aided design (CAD) systems based on artificial intelligence opens up the possibility for contemporary designers to create not only accurate but also intuitive and user-friendly project layouts.

Using deep learning and computer vision algorithms, AI systems can automatically recognize and generate 3D models, adapting them to design requirements. Such technologies are used in urban planning, park and garden design, architectural design, and other fields. They also help beginners and students of landscape architecture to master professional skills faster.

Innovative visualization technologies unlock amazing opportunities for the transformation of traditional two-dimensional sketches into volumetric three-dimensional models, which, undoubtedly, significantly enhances the overall perception of the future project as a whole. Moreover, they also actively contribute to establishing more effective and productive communication between designers, clients, and the entire working team, which, in turn, helps to prevent the occurrence of potential errors and ensures the high quality of the final implementation of the conceived idea.

Despite its significant potential, integrating AI into landscape design has its challenges. One of the main issues is the ethical aspect: overuse of AI can diminish the value of human creativity. It is important that AI remains a supporting tool, not a replacement for the role of the designer.

There are also technical difficulties, particularly related to data quality and possible algorithmic biases. To avoid this, it is necessary to critically evaluate input information and improve forecasting models.

In the very near future, artificial intelligence in the field of landscape design will transform into an even more powerful and multifunctional tool through close integration with advanced predictive analytics systems, innovative parametric modeling, and the continuous acquisition of real-world feedback, which will make it possible to create not only aesthetically pleasing but also maximally adapted to changing conditions and truly ecologically sustainable landscape spaces.

Additionally, open source platforms and cloud services will make AI technologies more accessible to a wider range of users, including civil society organizations, enabling a more inclusive and environmentally responsible approach to urban design.

The introduction of AI into landscape design is changing the way we create our environments. By harnessing the computational power of algorithms, designers can improve the efficiency and quality of their designs while addressing social and environmental challenges. Successful integration of AI will require not only technical improvements, but also ethical and social awareness of its impact. Thus, the landscape design of the future will not only be functional and beautiful, but also a tool for positive change in society and nature.

The Impact of Artificial Intelligence on The Diversity of Plant Design in Landscape Architecture.

Artificial intelligence (AI) is transforming various industries, including landscape design, by offering innovative tools to expand the possibilities of plant selection and application. The main areas of AI impact are:

- Plant Selection: Algorithms analyze soil, sunlight, climate data, and aesthetic preferences, helping designers create more diverse landscape compositions.
- Biodiversity conservation: AI promotes the inclusion of native, rare, or endangered species in projects, maintaining ecological balance.
- Design optimization: Artificial intelligence systems model changes in plant composition over time, taking into account seasonal variations and the environment.
- Data-driven design: Analyzing previous projects allows you to determine which plants are best adapted to specific conditions.
- Generative design: Intelligent algorithms in automatic mode generate diverse options for compositional solutions, which actively stimulates the conduct of creative experiments and facilitates the implementation of innovative ideas.
- Intelligent adaptive systems: Landscape solutions driven by artificial intelligence are characterized by the ability to flexibly and dynamically change in response to constant climate changes, thanks to the application of a complex of modern sensors and constantly updated data arriving in real time.
- Inclusivity: AI helps create accessible and comfortable spaces, taking into account the needs of different user groups.

Using AI in water resources management.

Through the analysis of large volumes of data and accurate forecasting, AI plays a key role in water management. The combination of geographic information systems (GIS) and AI allows you to optimize water resources management processes. Main stages of application:

1. Predictive modeling: AI assesses flood risks, water quality, and water consumption by integrating this data into GIS.
2. Real-time monitoring: Sensors and satellite imagery allow you to track weather conditions, water quality, and flow levels.
3. Data integration: AI combines information from different sources to gain a more complete picture of the state of water resources.
4. Decision-making: In the context of making critical management decisions, the application of comprehensive analytics plays a key role, helping to develop detailed scenarios and effective strategies for water resource management.
5. Optimize resource allocation: In the context of the efficient use of water resources, the application of advanced artificial intelligence algorithms ensures a noticeable increase in the efficiency of water usage for agricultural irrigation and meeting various other needs.

AI in Landscape Nutrient Management.

Artificial intelligence helps optimize plant health and landscape resilience through the following mechanisms:

- Soil analysis: Determining nutrient levels and selecting optimal fertilizers.
- Smart Fertilization: Taking into account fluctuating weather conditions, specific stages of plant growth and development, as well as their individual needs for precise dosing of mineral fertilizers.
- Forecasting nutrient needs: Using historical data to prevent nutrient deficiencies or excesses.

- Precise nutrient delivery: Automated fertilizer application based on soil conditions and plant needs.
- Remote sensing monitoring: Using satellites and drones to assess plant health and detect nutrient deficiencies.
- Decision support: Data analysis to develop effective fertilization strategies.
- Learning and improvement: AI adapts to changes in the environment, improving its recommendations over time.

Artificial intelligence opens up new possibilities for landscape design and resource management. Its application significantly contributes to the maintenance of environmental sustainability, the conservation of biological diversity, a more efficient allocation of available resources, and the overall optimization of plant care. The integration of AI into these areas makes landscape projects not only more aesthetic, but also functional and environmentally responsible.

The Role of Artificial Intelligence in The Fight Against Diseases and Pests.

Due to the rapid advancement of modern computer technologies, and particularly the progress in the field of artificial intelligence, there is a pronounced transition towards the implementation of automated expert systems in the critical area of plant disease and pest control, as well as in ensuring precise and highly efficient harvesting. Innovative information and communication technologies, such as wireless sensor networks, modern drones, high-precision GPS systems, user-friendly mobile applications, timely SMS messages (including USSD and voice services), informative web portals, and also RSS feeds, have fundamentally changed traditional approaches to monitoring the spread of diseases and pests, as well as in the process of advising gardeners and farmers.

Social media has created a convenient platform for farmers to interact with experts and receive real-time advice. Leading global IT corporations are actively developing innovative solutions for the agricultural sector, utilizing advanced artificial intelligence technologies for comprehensive support of the process of making informed decisions in the field of horticulture. Artificial intelligence plays an exceptionally important role in the effective fight against pests and various plant diseases, providing, in particular, the following:

- Early detection – Innovative systems powered by artificial intelligence conduct an in-depth analysis of diverse data, including digital images, current climatic conditions, and accumulated historical metrics, with the aim of promptly detecting the very first signs of disease development or the appearance of harmful insects, which ensures the possibility of a rapid response and a tangible reduction of potential damage.
- Accurate diagnosis – by analyzing plant images, artificial intelligence is able to recognize diseases and insect infestations, suggesting effective treatment methods.
- Risk prediction – AI algorithms analyze environmental factors such as temperature, humidity, and precipitation to predict potential disease outbreaks and to develop a set of preventive measures.
- Improvement of treatment methods - by conducting a thorough analysis of the effectiveness of various control methods, artificial intelligence proposes the most optimal treatment options, while taking into account various factors, including financial costs, potential environmental impact, and a range of other important variables.
- Targeted application of protection products – robotic drones and intelligent systems allow for more precise application of pesticides and similar products, which reduces their consumption and positively impacts the ecology.
- Data-driven decision-making – Using information from various sources, intelligent systems help gardeners make more informed decisions to ensure plant health.
- Continuous monitoring – Artificial intelligence systems continuously monitor changes in plant health and, based on the information obtained, adapt pest control approaches in real-time.

- To minimize the harmful impact on the environment, through the precise and judicious application of chemical agents, AI systems are instrumental in maintaining the delicate balance of ecosystems, which is of paramount importance.

In conclusion, the implementation of artificial intelligence technologies within the realm of combating diseases and pests not only reduces risks and boosts yields but, crucially, also supports the health of orchard cultivations, all achieved through the application of exceptionally precise and effective methodologies.

The Use of Robots in Landscape Management.

Intelligent robots, equipped with advanced artificial intelligence technologies, are playing an increasingly crucial role in the modern field of landscape management. These robots are capable of effectively adapting to diverse environmental changes, rapidly analyzing large volumes of information, and making independent decisions. Autonomous vehicles, industrial and service robots, as well as drones, are just some of the numerous systems that utilize sophisticated artificial intelligence algorithms to process data obtained from a variety of sensors and surveillance cameras.

The main advantages of robots in landscape management:

- Increased labor efficiency – automating labor-intensive processes such as mowing, pruning, or weeding reduces the need for manual labor.
- Cost reduction – although the initial investment may be significant, in the long run the works reduce operating costs.
- High accuracy in task performance – robots ensure consistent and uniform task performance, which is important for landscape maintenance.
- Environmental safety – using electric robots reduces CO_2 emissions and the need to use chemicals.
- 24/7 operation – unlike humans, robots can work without interruption, allowing for continuous service of territories.
- Increased safety – automating dangerous tasks, such as pruning trees or working on steep slopes, reduces the risk of injuries.
- Data monitoring and analysis – robots can collect information about soil condition, moisture levels, and plant health to optimize care.
- Scalability – robotic systems can be used both in private gardens and in large-scale park areas.

Examples of using robots in landscape maintenance:

- Robotic lawn mowers are autonomous systems that operate along a set route, avoid obstacles, and provide a high-quality lawn cut.
- Automated weeding – AI-powered robots identify weeds and remove them, reducing the need for herbicides.
- Plant pruning robots – recognize the shape and condition of plants, perform precise pruning to improve their growth.
- Robotic planting systems are automated solutions for planting seeds, seedlings or bulbs with high precision.
- Systems for applying fertilizers and pesticides are autonomous robots that analyze the condition of plants and apply the necessary preparations in a dosed manner.
- Monitoring work - to ensure proper care, the monitoring process includes the systematic collection of diverse data, including information on the overall condition of plants, current humidity levels, as well as other key factors that directly affect the health and productivity of the garden.

Overall, the introduction of robotic technologies into landscape management allows for increased care efficiency, reduced costs, and reduced environmental impact, ensuring the sustainability and durability of landscape systems.

Robotics in landscape maintenance. Using robots for tree pruning and planting. Autonomous robots that perform tree trimming or planting functions face numerous challenges in the field of horticulture. Landscape features such as uneven terrain, dense green cover, and a variety of objects create significant obstacles for computer vision algorithms. Dynamic environmental changes caused by seasonal fluctuations and natural plant growth complicate the process of navigation and accurate task performance.

Fluctuating lighting conditions, which vary based on the time of day and weather patterns, significantly impact color perception and the overall performance of computer vision systems. Furthermore, robotic systems themselves actively modify their surroundings during operation, for instance, by performing pruning of bushes and trees. This dynamic alteration of the landscape considerably complicates the process of timely updating of terrain maps, which are essential for effective navigation. Robots must navigate diverse and challenging terrain conditions, including grassy areas, sidewalks, and various obstacles such as gravel or wood chips. Moreover, the complexity of precisely modeling plant shapes, particularly ornamental plantings, necessitates the development of highly accurate algorithms for correct pruning and effectively maintaining the desired shape.

One of the primary challenges lies in the accurate comparison of actual plant shapes with desired ones, while it's crucial to consider various geometric constraints, as well as to leverage in-depth expert knowledge regarding plant care. Furthermore, the process of precisely guiding cutting tools to a designated point is additionally complicated by the inherent flexibility of the plants and the noticeable influence of diverse external factors, such as, for instance, gusts of wind.

Expert systems for landscape management. While artificial intelligence has already made an undeniable significant impact on landscape design, its application in the field of landscape maintenance is still quite limited. The implementation of intelligent systems in landscape maintenance practice faces a number of the following challenges and difficulties:

- Response time and accuracy. Key factors that determine the effectiveness of an expert system are, undoubtedly, the speed of its functioning, and also, no less importantly, the high accuracy of the results obtained. Delays in response or insufficient accuracy can affect the user's choice of certain landscape maintenance strategies.
- Data volume: One of the key obstacles on the path to the effective implementation of intelligent systems is the necessity to process colossal volumes of data in real-time. Furthermore, a critically important task becomes the filtering and sifting out of secondary information, which, undoubtedly, significantly complicates their practical realization.
- Execution Methodology: Using big data requires effective learning and information retrieval methods to achieve optimal performance.
- Data cost: Most AI systems operate over the internet, which limits their use in remote areas.
- System flexibility. Reliable intelligent solutions must easily adapt to changing environmental conditions.

The integration of artificial intelligence in landscape care opens up prospects for automating processes and increasing efficiency, including:

- At the heart of the concept of autonomous landscape management lies the application of advanced artificial intelligence algorithms to carry out so-called predictive, or prognostic, maintenance. This approach involves in-depth analysis of data coming from various sensors that record environmental conditions, as well as a thorough study of accumulated historical records. The goal of this is not only the rapid detection, but also, and more importantly, the effective prevention of potential problems, such as the spread of pests, the occurrence of plant diseases, or unforeseen malfunctions in irrigation systems, which ultimately contributes to a significant increase in the efficiency and sustainability of landscape management..
- Carefully developed personalized landscape design projects are intended to take into account a wide range of factors, including, first and foremost, the unique environmental conditions of a specific site, the client's individual aesthetic preferences, as well as clearly defined functional requirements for the future landscape space.

- Active support for biodiversity and effective ecosystem restoration is achieved through intelligent systems based on artificial intelligence. These systems are capable of carrying out comprehensive monitoring of both plant and animal populations, timely detecting invasive species, and accurately identifying areas that require priority protection and restoration to preserve natural harmony.
- Digital assistants for gardening are user-friendly chatbots and mobile applications that provide users with valuable personalized recommendations for plant care, as well as prompt troubleshooting of various problems that may arise in the gardening process.

Overall, the progressive development of artificial intelligence technologies significantly contributes to the creation of not only more sustainable and environmentally safe, but also exceptionally functional landscapes. This, in turn, promotes the enrichment of the natural environment as a whole and, undoubtedly, improves the quality of life for entire communities.

Choosing Plants Taking Into Account Climate and Soil.

Artificial intelligence is revolutionizing the process of selecting plants for landscaping through sophisticated data analysis algorithms. Modern AI systems analyze over 50 soil and climate parameters to create optimal plant combinations.

Algorithmic plant selection includes:

- Analysis of soil pH and its mineral composition.
- Estimate the annual precipitation level.
- Study of temperature fluctuations.
- Research on the level of solar activity.
- Taking into account wind loads.

Integrating native plant species into garden design plays a crucial role in shaping ecologically sustainable and self-renewing ecosystems, which is exceptionally important for maintaining the natural balance and preserving the environment. Systems that utilize artificial intelligence are capable of effectively identifying specifically those native plant species that:

1. Requires less care and resources.
2. Support local fauna.
3. They maintain the natural balance of the ecosystem.
4. Adapted to local climatic conditions.

Modern sustainable gardening is based on AI recommendations to create viable garden spaces:

1. Grouping plants by water needs.
2. Creating multi-tiered plantings.
3. Using natural methods of pest control.
4. Introduction of seasonal crop rotation.

AI technologies allow for the creation of individual care plans for each plant, taking into account the specific conditions of the site. Artificial intelligence systems are constantly learning based on data from thousands of gardens, improving the accuracy of recommendations and plant growth predictions.

Smart algorithms also help create planting maps taking into account:

- Compatibility of species.
- Seasonality of flowering.
- Nutrient needs.
- Spatial location.

Artificial intelligence helps create sustainable garden compositions that require minimal human intervention and are as close to natural ecosystems as possible.

Plant Health Monitoring and Management Technologies.

Modern artificial intelligence technologies allow you to create a "smart garden" where plant care is done automatically and with maximum efficiency, for which a number of automation tools have already been created [1].

Intelligent monitoring sensors:
- Soil moisture sensors measure water levels at different depths.
- Temperature sensors monitor the microclimate around the plants.
- UV sensors control the light level.
- pH meters analyze soil acidity.

Automated care systems:
- Smart irrigation systems are activated based on moisture data.
- Fertilizer dispensers operate on a schedule set by AI.
- Automatic lighting control for greenhouse plants.
- Ventilation systems maintain optimal temperatures.

Garden health analytics:
- AI analyzes data from all sensors in real time.
- Algorithms detect early signs of plant diseases.
- The system generates daily reports on the condition of each plant.
- The owner receives push notifications about critical changes.

Preventive measures:
- AI predicts potential problems based on historical data.
- The system provides recommendations for preventive measures.
- Automatic adjustment of care parameters prevents plant stress.
- Algorithms take into account seasonal changes and weather conditions.

The integration of these technologies creates a self-sufficient ecosystem where each plant receives individual care without constant human intervention. Artificial intelligence provides optimal conditions for plant growth and development, minimizing the risks of disease and stress.

Predicting Trends in Landscape Design Using AI.

Artificial intelligence opens up new possibilities for predicting future trends in landscape design. AI systems analyze huge data sets that include:
- Historical design trends.
- User search queries.
- Social media activity.
- Data on sales of gardening materials.
- Climate change and its impact on landscape design.

Consumer feedback analysis has become a key factor in shaping future projects. In this case, AI allows you to quickly collect and process the following data sets:
- Comments on specialized forums.
- Reviews about implemented projects.
- Client requests to landscape designers.
- User reactions on social networks.

Based on this data, AI predicts an increase in demand for:
1. Vertical gardening for small spaces.
2. Biophilic design with the integration of natural elements.
3. Smart garden care automation systems.
4. Plants resistant to climate change.
5. Edible landscapes and urban gardens.

AI identifies changes in consumer behavior through analysis of:

- Demographic trends.
- Urbanization processes.
- Environmental awareness.
- Economic factors.

Artificial intelligence systems predict an increase in demand for multifunctional garden spaces that combine:

1. Recreation areas.
2. Places to grow food.
3. Natural habitats.
4. Technological solutions for garden care.

Integrating artificial intelligence into landscape design poses a number of industry-specific challenges. Data security is a critical issue when implementing AI technologies into landscaping projects.

Main data security issues:

- Protecting confidential customer information.
- Preservation of intellectual property of design solutions.
- Risks of unauthorized access to control systems.
- Vulnerability of sensor networks and IoT devices.

At the same time, training personnel requires significant resources and time; specialists must master:

1. Working with AI design tools.
2. Data analysis and interpretation of results.
3. Setup and maintenance of "smart" systems.
4. Integration of various technological solutions.

Barriers to adapting new technologies:

Psychological resistance to change among employees often slows down the implementation of innovations. Experienced professionals may be skeptical of AI solutions, preferring traditional working methods.

Financial challenges include:

- The high cost of AI hardware and software
- Staff training costs
- The need for constant system updates
- Investment in cybersecurity

Technical difficulties arise when:

1. Integration of various software platforms
2. Ensuring a stable internet connection
3. Adjusting the accuracy of AI algorithms
4. Adaptation of systems to local conditions

Successfully overcoming these challenges requires a systematic approach and phased implementation of technologies, taking into account the specifics of each project and the capabilities of the team.

Technological innovations are rapidly changing landscape design, creating new opportunities for gardening and urban greening. Forecasts for the 2030s show exciting prospects for the industry.

Predicted trends for the 2030s:

- Smart plant care systems - automated AI-based systems for monitoring plant health.
- Edible landscaping is the integration of food crops into the urban landscape.
- Regenerative gardening - a focus on soil restoration and carbon sequestration.
- Climate-adaptive gardening - sustainable solutions for extreme weather conditions.

Innovative spatial solutions. Vertical farms and gardens are becoming an answer to the limited urban space:
- Smart container gardens.
- Rooftop gardens with AI control.
- Vertical green walls with automated irrigation.
- Multi-tiered urban greenhouses.

Biophilic design. The biophilic approach combines natural elements with architecture:
- Integration of living plants into building facades.
- Creation of natural microecosystems.
- The use of organic shapes in design.
- Use of natural materials.

The humanistic aspect of gardening. Interaction with nature remains a key element of gardening:

Therapeutic practices:
- Sensory gardens.
- Meditative spaces.
- Community gardens.
- Green areas for rehabilitation.

Technology support:
- AI assistants for therapeutic gardening.
- Virtual garden tours.
- Personalized garden therapy programs.
- Monitoring the psychological impact of green areas.

Autopilot functions. Smart systems provide garden care during the owner's absence:
- Automatic watering.
- Pest monitoring.
- Lighting adjustment.
- Microclimate control.

The future of gardening is envisioned in a close integration of advanced technological innovations and refined natural aesthetics. Specifically, in landscape design, artificial intelligence technologies unlock entirely new perspectives for developing not only innovative, but also significantly more effective solutions compared to traditional approaches.

Key aspects of AI's impact on landscape design:
- Automation of routine design processes.
- Generation of creative design concepts.
- Optimizing the use of space and resources.
- Predicting plant growth and environmental impact.

Modern landscape architecture is confronted with the complex challenges of ever-increasing urbanization and the pressing need to create truly ecologically sustainable green spaces within urban environments. In these circumstances, artificial intelligence is becoming a reliable tool in addressing these crucial problems, utilizing the powerful capabilities of intelligent data analysis and innovative automated design. It's worth noting that artificial intelligence is fundamentally transforming the traditional approach to the process of creating both private gardens and large public parks. Let's examine in more detail the main promising trends that are already actively defining the future direction of modern landscape architecture.

1. Automated design of green areas:
- Generate multiple design options in minutes.
- Optimization of plant placement taking into account local conditions.
- Creating 3D visualizations of future projects.

2. Smart control systems:
- Automatic irrigation control based on soil moisture data.
- Monitoring plant health using computer vision.
- Forecasting needs for green space maintenance.

3. Environmental optimization:
- Analysis of the impact of projects on the local ecosystem.
- Calculating the carbon footprint of landscape solutions.
- Plant selection for maximum biodiversity.

Urbanization creates new challenges for landscape architects. AI helps find innovative solutions:
- Vertical gardening with automated care systems.
- Integrating "smart" elements into city parks.
- Creation of micro-parks in dense urban areas.

4. Innovations in design:
1. Using visitor traffic data to optimize routes.
2. Adaptive lighting based on user activity.
3. Integration of AR technologies to improve interaction with space.

5. Personalization of public spaces:
- Analysis of local community needs.
- Adapting the design to different age groups.
- Creation of multifunctional recreation areas.

Artificial intelligence technologies play a key role in the development of more ecologically sustainable and adaptive landscape solutions. Machine learning systems conduct in-depth analysis of diverse data, including information about climate conditions, soil type, and local flora, with the aim of optimizing design solutions. Thanks to this, it becomes possible to create spaces that are not only visually appealing and aesthetically refined, but also, and no less importantly, ecologically balanced and harmonious with the surrounding environment.

Basic Artificial Intelligence Technologies Used in Landscape Design.

In contemporary landscape design, there is an active trend towards integrating three core artificial intelligence technologies: machine learning (ML), deep learning (DL), and computer vision (CV). These advanced technologies, which are foundational for numerous innovative solutions, are playing an increasingly important role in shaping effective and aesthetically pleasing landscapes of the future.

Machine learning in green space design. ML algorithms analyze large datasets of successful landscape projects and create optimized solutions for new spaces. You get:
- Automatic selection of plants taking into account climatic conditions.
- Forecasting the growth and development of green spaces.
- Optimization of irrigation and maintenance systems.
- Calculation of the optimal location of landscape elements.

Deep learning for creating innovative designs. DL systems are capable of generating unique design solutions based on given parameters:
- Creating 3D landscape models.
- Generation of territory planning options.
- Adaptation of existing designs to new conditions.
- Simulation of seasonal changes in the landscape.

Computer vision in spatial analysis. CV technologies transform visual data into practical solutions:
- Analysis of the topography of the area through aerial photography.
- Recognizing vegetation types and their condition.
- Creating accurate 3D maps of existing landscapes.
- Monitoring changes in the landscape in real time.

The practical application of these technologies allows for the creation of "smart" landscape designs. For example, a computer vision system analyzes the illumination of the site throughout the day and suggests the optimal location of plants with different needs for sunlight.

ML algorithms are already helping designers create sustainable ecosystems, taking into account the interaction of different plant species, soil characteristics, and climate factors. DL models generate land-use planning options that best meet user needs and environmental requirements.

The integration of these technologies creates new opportunities for automating routine tasks and improving project quality.

Generative networks are a new stage in the development of landscape design. This technology allows you to generate unique design solutions based on existing examples and given parameters.

Key features of GAN in landscape design:

- Creating realistic visualizations of future projects.
- Generation of planning options taking into account specified constraints.
- Adaptation of existing design solutions to specific conditions.
- Modeling seasonal landscape changes.

GAN analyzes thousands of examples of successful landscape projects and creates new concepts that meet aesthetic and functional requirements. The system takes into account terrain features, climatic conditions and environmental factors when generating design solutions.

Practical applications of GANs include [2]:

1. Visualization of various landscaping options.
2. Creation of 3D models of landscape compositions.
3. Forecasting plant growth and landscape changes.
4. Optimization of the placement of landscaping elements.

Integrating GANs into the workflow allows designers to quickly create and evaluate different layout options. The technology does not replace human creativity, but rather enhances it by providing tools for experimenting with shapes and compositions [3]. Benefits of using GANs:

- Reducing time for concept development.
- Ability to create an unlimited number of options.
- Taking into account the complex relationships between landscape elements.
- Increasing the realism of visualizations.

Modern GAN systems are capable of generating not only static images, but also dynamic models of landscape development, demonstrating what the area will look like a few years after the project is implemented.

The implementation of artificial intelligence in landscape architecture unveils a range of promising advantages while simultaneously posing certain challenges that must be considered. Undoubtedly, artificial intelligence technologies offer unique opportunities for developing environmentally responsible and sustainable landscape projects, which is crucial in today's world. Let's examine in more detail the key advantages, as well as potential difficulties, associated with the active implementation of these innovative technologies into the practice of landscape architecture.

Environmental benefits:

- Water resource optimization: AI systems analyze weather conditions, soil moisture, and plant needs to create effective irrigation schemes.
- Biodiversity: Algorithms help select optimal plant combinations to create sustainable ecosystems.
- Plant health monitoring: Computer vision systems detect diseases and pests at early stages.

Project management:

- Automating routine tasks: AI takes over technical calculations and documentation.
- Plant growth prediction: Algorithms model the development of green spaces over the years.
- Budget optimization: Systems analyze costs and offer cost-effective solutions.

Data quality:

- The difficulty of collecting reliable information about local conditions.
- The need for regular database updates.
- High cost of high-quality datasets.

User safety:

- Protection of personal data of park visitors.
- Cybersecurity of control systems.
- Risks of unauthorized access to project documentation.

Technical limitations:

- The need for a powerful computing infrastructure.
- Difficulty integrating with existing systems.
- The need for specialized training for staff.

Implementing AI requires a balance between innovation and preserving traditional approaches to landscape design. Successful integration of technology depends on the team's willingness to adapt to new working methods and the ability to solve technical challenges.

Modern Solutions For Landscape Management Using AI.

Smart landscape management systems are transforming traditional methods of landscape maintenance. Artificial intelligence creates new opportunities for automating and optimizing green space maintenance processes.

Intelligent irrigation systems. Intelligent irrigation systems play a key role in modern landscape management:

- Real-time weather analysis.
- Automatic adjustment of the watering schedule.
- Optimization of water consumption.
- Soil moisture monitoring.
- System malfunction warning.

Monitoring the condition of vegetation. Sensors and sensors integrated with AI algorithms provide constant monitoring of the condition of vegetation:

- Detection of plant diseases at early stages.
- Monitoring the level of nutrients in the soil.
- Tracking plant growth rates.
- Determining the optimal time for pruning.
- Forecasting fertilizer needs.

Practical applications of AI systems. Practical applications of AI systems include:

1. Automated greenhouses with microclimate control.
2. Robotic lawn mowing systems.
3. Drones for monitoring large areas.
4. Mobile applications for landscape management.
5. Pest early warning systems.

The harmonious integration of these advanced technologies unlocks opportunities for creating a holistic ecosystem designed for effective landscape management. Artificial intelligence conducts a comprehensive analysis of data obtained from various sources of information, generates exhaustive recommendations based on this analysis, and, crucially, in automatic mode, promptly adjusts key plant care parameters. The implementation of such an intelligent approach ensures the creation of the most favorable and optimal conditions for the active growth and healthy development of plants, while simultaneously helping to achieve significant savings and minimize the consumption of various resources.

Innovative Technologies For Creating Landscaped Facilities of The Future

Modern SMART solutions are radically changing the approach to the design and maintenance of landscaped facilities. Innovative technologies allow you to create more efficient and sustainable green spaces.

Key design innovations:

- *3D scanning of the territory*- the technology creates an exact digital copy of the landscape for further modeling.
- *Parametric design*- automates the process of creating complex geometric shapes and optimizes the placement of elements.
- *Virtual Reality (VR)*- allows you to visualize the future project on a real scale.
- *Augmented Reality (AR)*- overlays digital elements on real space for better planning.

Construction and maintenance automation:

- Robotic systems for planting plants.
- Autonomous lawn mowers with GPS navigation.
- Drones for monitoring the condition of green spaces.
- Systems for automatic collection and processing of fallen leaves.

Smart systems integration:

1. Adaptive lighting that responds to the presence of visitors.
2. Air quality and noise level sensors.
3. Rainwater harvesting systems with smart distribution.
4. Interactive information stands with AI assistants.

These mentioned advanced technological solutions are capable not only of significantly optimizing various work processes, but also, and particularly valuable, of opening up fundamentally new horizons for visitors regarding their full interaction with the surrounding natural environment. The implementation of intelligent systems, based on artificial intelligence, into the overall management system provides a unique opportunity to effectively predict and proactively prevent the occurrence of potential problematic situations, thereby ensuring the long-term stability and uninterrupted functioning of various facilities of garden and park designation.

On the path to the effective implementation of artificial intelligence in landscape architecture, a number of significant challenges arise, among which particularly stand out the need for obtaining high-quality data for training relevant models, the complexity of integrating cutting-edge technologies into existing workflows, as well as the pressing necessity for specialized knowledge and qualifications for fully working with artificial intelligence systems. One of the most substantial problems is precisely the need for large volumes of first-rate data necessary for training artificial intelligence models. It is critically important to ensure continuous access to accurate, representative, and reliable information, encompassing various aspects of landscapes, plant species, soil types, and other crucial factors that directly influence the process of designing gardens and parks. The process of integrating new technological solutions into already established workflows also requires particular attention and a meticulous approach. For the guaranteed successful implementation of artificial intelligence in the field of landscape architecture, it is essential to ensure full compatibility of new developments with existing systems and strive for the most effective complementary use of them.

Furthermore, the successful implementation of Artificial Intelligence necessitates in-depth specialized knowledge and versatile practical skills. This encompasses not only the initial setup and configuration of AI systems, but also their ongoing management and maintenance, alongside the meticulous analysis of the resulting data to uncover valuable insights. Considering this, landscape architecture professionals must be prepared to proactively acquire these essential competencies. Their acquisition is critically important to effectively utilize the full potential that AI offers within this field. While integrating Artificial Intelligence technologies into landscape architecture involves a degree of effort and investment, it undoubtedly paves the way for realizing substantial advantages. Notably, it will enable the creation of more sustainable, ecological, and effective solutions for shaping natural environments that are not only functional but also harmoniously integrated into the surrounding context.

Artificial Intelligence is capable of becoming a powerful tool for addressing complex ecological challenges, prominently including the rational management of water resources, the conservation of biodiversity, and the noticeable improvement of atmospheric air quality. Thanks to its ability to process and analyze large datasets, Artificial Intelligence can assess ecosystem needs with remarkable speed and high accuracy. Based on this analysis, it offers optimal solutions for selecting locations for planting vegetation, effective irrigation management, and other crucial aspects of landscape design. As a result of this approach, multifunctional and ecologically resilient green spaces are created, which not only noticeably improve people's quality of life but also contribute to increasing the stability and resilience of ecological systems. Thus, the application of Artificial Intelligence in landscape design can become a key factor in achieving a harmonious balance and sustainable interaction between natural and artificially created environments. Additionally, the implementation of Artificial Intelligence also plays a significant role in reducing overall energy consumption and decreasing harmful emissions into the atmosphere. For example, intelligent automated irrigation systems can effectively optimize water usage, virtually eliminate water waste, and ensure optimal conditions for plant growth and development. Artificial Intelligence is also capable of intelligently managing lighting in parks and gardens, which significantly helps reduce unnecessary electricity consumption. The combination of these factors contributes to the creation of an ecological and sustainable infrastructure that actively helps improve the state of our environment and preserve valuable natural resources for future generations.

Smart Cities.

Also, modern technologies can be used to implement “smart” lighting in cities. LED lamps with a control system allow you to automatically adjust the brightness of the lighting depending on weather conditions or traffic intensity. This not only saves electricity, but also improves safety on the streets, especially at night.

Consequently, the implementation of modern technologies is capable of significantly facilitating the everyday lives of urban residents and making a substantial contribution to achieving sustainable urban development. The continuously growing interest in the concept of “smart” cities clearly indicates that further innovative work in this direction is exceptionally important and forward-looking. After all, the comprehensive utilization of advanced technological solutions is capable not only of simplifying the routine aspects of city life but also of qualitatively improving the urban environment as a whole, contributing to its greening and the optimization of resource utilization. Another defining aspect of a “smart” city, undoubtedly, is the enhancement of the overall quality of life for its inhabitants. An example of this is the organization of high-quality lighting in public spaces, which not only guarantees a proper level of safety and increases the sense of comfort among the urban community but also actively stimulates social interaction between people and promotes their more active lifestyles, especially during evening hours.

The realization of these ambitious goals becomes fully achievable through the active application of advanced sensor technologies. These technologies enable the continuous collection of diverse data, including indicators of weather conditions, traffic flow intensity, levels of atmospheric air pollution, and a whole range of other important parameters that directly affect the quality of life of urban residents. The information obtained from these numerous sources can be effectively utilized for the comprehensive optimization of the operations of various municipal services and for a significant increase in the efficiency of urban planning processes at all levels. Intelligent and well-considered management of key resources, such as energy and water, also plays a crucial role in ensuring not only the economic efficiency of the urban economy but also the long-term ecological sustainability of the entire urban environment. Thus, the “smart” city concept not only significantly contributes to improving the overall quality of life of the urban population but also simultaneously creates a solid and favorable foundation for further economic development and a tangible increase in the city's competitiveness in the modern digital world.

A critically important aspect within the concept of a smart city is ensuring a reliable level of security and effective data protection. The active collection and comprehensive processing of significant volumes of diverse information, which is an integral part of the functioning of a "smart" city, can potentially become a serious source of various cybernetic risks and threats. This becomes a reality in cases where appropriate and timely cybersecurity measures, capable of effectively preventing such risks, are not implemented. Considering this, developers of technological solutions for smart cities must treat this issue with particular attention. Their primary task should be to guarantee the reliable protection of both the personal data of city residents and the confidential information belonging to the municipality and urban services, from unauthorized access and potential cyberattacks.

Furthermore, in the process of building a "smart" city, it is critically important to steadfastly remember the principles of social justice and inclusivity. During the active implementation of the latest technological solutions, it is paramount to primarily consider the needs of absolutely all population groups, without any exceptions or preferences for individual social groups or specific geographical areas of the city. This approach will effectively help prevent the further deepening of social inequality and potential stratification within the urban community, ensuring equal access to the benefits of civilization for every resident. Thus, the widespread introduction of "smart" technologies in the urban environment opens up a multitude of significant advantages and opportunities, but at the same time inevitably requires a comprehensive and balanced solution to a whole range of complex challenges and potential problems. Ensuring efficient management of urban resources, comprehensive preservation of the environment, guaranteeing a high level of safety for all citizens, and unwavering adherence to the principles of social justice are just some of the key aspects that should be given close attention and primary focus when developing and implementing the "smart" city concept.

Modern Technologies and AI Software Applications in The Design of Garden and Park Facilities

Artificial intelligence (AI) is rapidly changing the paradigm in the world of landscape architecture and garden design, opening up fundamentally new horizons for the design and visualization of diverse garden and park facilities. AI effectively contributes to the realization of modern trends in this field through the utilization of intelligent algorithms that are capable of processing colossal volumes of data and offering the most optimal solutions for each individual project, considering its unique features and requirements. This innovative technology demonstrates an impressive ability to significantly reduce water consumption – by up to 30% – and noticeably increase biodiversity – by up to 20% – within garden and park spaces. Modern landscape design is undergoing an era of profound transformation, made possible by powerful Artificial Intelligence tools. Let's consider in more detail the key AI-powered technologies and their practical application in the process of creating unique and functional garden and park complexes.

Leading AI platforms for design:

Midjourney

- Creating photorealistic visualizations of garden spaces.
- Generation of various landscape design options.
- The opportunity to experiment with different styles and compositions.
- Quick visualization of ideas for presentation to clients.

DALL-E

- Transforming text descriptions into visual concepts.
- Generation of unique garden design elements.
- Creating variations of existing design solutions.
- Adapting the design to different seasons and weather conditions.

Generative design in landscape architecture. Generative design uses AI algorithms to generate optimal solutions based on given parameters:

- Analysis of the topography and natural conditions of the site.
- Calculation of optimal plant placement.
- Design of irrigation and drainage systems.
- Creating ecologically balanced compositions.

Generative design tools:

- *ArcGIS GeoPlanner*- spatial data analysis.
- *CityEngine*- 3D landscape modeling.
- *UrbanSim*- simulation of territorial development.
- *ARIES*- mapping of ecosystem services.

Innovations in concept creation. AI is changing traditional approaches to landscape design:

Process automation:

- Quick analysis of soil conditions.
- Selection of plants according to given parameters.
- Optimization of irrigation systems.
- Plant growth prediction.

Design personalization:

- Taking into account the customer's individual wishes.
- Adaptation of projects to local climatic conditions.
- Creating unique landscape solutions.
- Optimizing garden care.

Thorough analysis of historical weather conditions, mandatory consideration of local flora and fauna peculiarities, as well as a comprehensive assessment of potential environmental impact - these are extremely important aspects that need to be taken into account when designing new garden and park facilities. Artificial intelligence is radically transforming the garden design process, opening up a whole range of significant advantages and new opportunities for landscape architects and gardeners.

Personalization and design optimization:

- Analysis of individual user needs.
- Taking into account the characteristics of the site and microclimate.
- Creating unique design solutions for each project.
- Adaptation of projects to budget constraints.

Effective resource management:

- Reducing water consumption by 30% thanks to smart irrigation systems.
- Optimizing plant placement to maximize use of natural light.
- Minimizing garden maintenance costs.
- Reducing pesticide use by 30% through accurate plant health monitoring.

Supporting biodiversity:

- Recommendations for local plant species.
- Creating balanced ecosystems.
- Selection of plant combinations to attract beneficial insects.
- 20% increase in biodiversity compared to the traditional approach.

Improving aesthetic appeal:

- Generation of harmonious color schemes.
- Taking into account seasonal changes in design.
- Creating visually appealing compositions.
- Balance between functionality and aesthetics.

Intelligent monitoring:
- Automatic detection of plant diseases.
- Forecasting care needs.
- Optimization of the maintenance schedule.
- Warning of potential problems.

The use of AI allows you to create "smart gardens" that not only meet aesthetic requirements, but also contribute to the conservation of natural resources. Artificial intelligence systems analyze data on soil composition, lighting, climatic conditions and automatically adjust garden care parameters.

AI technologies provide accurate prediction of plant growth and their interactions, which allows for the creation of long-term sustainable landscape solutions. The integration of AI into garden design contributes to the formation of an environmentally responsible approach to landscaping and landscaping.

Challenges and Limitations of Utilizing Artificial Intelligence in Garden Design. The integration of Artificial Intelligence technologies into the realm of garden design inevitably gives rise to a series of significant challenges and potential limitations, which necessitate close attention, thorough examination, and effective resolution:

Technical limitations:
- The difficulty of adapting AI to unique local conditions.
- Insufficient accuracy in recognizing complex natural ecosystems.
- Limited database on regional plant characteristics.

Creative aspects:
- AI can generate standardized solutions, losing the individuality of projects.
- The risk of diminishing the role of human intuition and artistic vision.
- The difficulty of conveying cultural context and historical value.

Ethical issues:
- Protection of users' personal data.
- Copyright issues on generated design.
- Risks of algorithmic bias in decision-making.

The issue of human autonomy in the design process is becoming increasingly relevant. Designers of landscape objects face a dilemma: how to maintain a balance between the technological capabilities of AI and their own creativity.

Practical implementation challenges:
- High cost of developing and implementing AI systems.
- The need for constant database updates.
- The need for special training for staff.

There is a very real risk of over-reliance on Artificial Intelligence technologies, which, in the long run, could lead to a gradual loss of valuable traditional landscape design skills that have been developed over centuries. Leading industry professionals consistently emphasize the paramount importance of preserving the "human factor" in the creative process of landscape design. They stress that, despite the impressive capabilities of AI, it is precisely human intuition, artistic vision, and a deep understanding of aesthetic principles that remain irreplaceable for creating truly harmonious and emotionally rich landscape spaces that reflect the individuality of each project and the needs of the client.

Technological limitations:
- The difficulty of taking into account microclimatic features.
- Limited ability to predict long-term plant development.
- The inability to fully take into account the customer's aesthetic preferences.

AI can be a powerful tool, but it is not a complete replacement for human expertise and creativity. It is important to understand the limits of AI capabilities and use it as an aid, not as a complete replacement for the professional expertise of landscape architects.

The Future Use of AI in Garden Design

The development of artificial intelligence in garden design opens up new opportunities for creating innovative and environmentally conscious garden and park facilities. AI technologies are changing towards personalized solutions that take into account the individual needs of users and the peculiarities of the local environment.

Key trends of the future:

4. Smart monitoring systems.
   - Integration of sensors to track plant health.
   - Automatic adjustment of growing conditions.
   - Forecasting diseases and pests.
5. Automation of care.
   - Robotic systems for pruning and weeding.
   - Intelligent irrigation systems.
   - AI-controlled drones for monitoring large areas.
6. Biophilic design.
   - Creation of natural ecosystems.
   - Integration of local plant species.
   - Supporting biodiversity.

Sustainable practices of the future. AI will promote the development of environmentally responsible horticulture through:

1. Resource optimization.
- Reducing water consumption by 40-50%.
- Minimizing the use of pesticides.
- Effective use of fertilizers.
2. Adaptation to climate change.
- Selection of resistant plant species.
- Creation of microclimatic zones.
- Forecasting extreme weather conditions.
3. Circular economy.
- Recycling of organic waste.
- Use of renewable materials.
- Closed water use cycles.

Artificial Intelligence technologies are relentlessly and rapidly evolving towards the creation of intelligent “living” gardens that are capable of dynamically adapting to constant changes in the surrounding environment and the individual needs of users. The close integration of advanced machine learning with the Internet of Things (IoT) concept will pave the way for the creation of truly self-sufficient and autonomous garden ecosystems. Such systems will be able to function virtually without constant human intervention, independently maintaining an optimal balance. Further development of cloud technologies and powerful big data processing methods will provide Artificial Intelligence with a unique opportunity to analyze the accumulated experience of the functioning of thousands of diverse gardens around the world. Based on this global data, AI will be able to generate the most effective and verified solutions for each specific case of landscape design, taking into account all its unique parameters and goals. All these achievements, taken together, will inevitably lead to the emergence of a completely new generation of “smart gardens” that will qualitatively change our understanding of the organization of natural space.

The integration of artificial intelligence into landscape architecture creates a powerful symbiosis of traditional design methods and innovative technologies. This synergy opens up new opportunities for creating aesthetically appealing and environmentally sustainable garden and park facilities.

Key aspects of AI's impact on landscape design:

- Optimization of design processes while preserving the designer's unique creative vision.
- Increasing the efficiency of natural resource use.
- Creating personalized solutions taking into account local characteristics.
- Improving biodiversity and environmental sustainability of projects.

Artificial intelligence does not replace human creativity and experience - it enhances them. Professional designers receive a powerful tool to implement their ideas, while preserving the authenticity and cultural heritage of landscape architecture.

The application of Artificial Intelligence in garden design encompasses the provision of individualized recommendations, the optimization of resource utilization, and active support for the principles of sustainable gardening. This includes the development of personalized advice aimed at satisfying the unique needs of each client, the efficient use of valuable resources such as water and energy, as well as the promotion of environmentally responsible methods of garden and park management. This contributes to significant conservation of water resources, which is especially crucial in regions with limited water supply, a noticeable improvement in biodiversity due to the creation of favorable conditions for various species of plants and animals, and a tangible enhancement of the aesthetic appeal of garden spaces, making them more harmonious and pleasing to the eye. By analyzing vast datasets that include information on climatic conditions, soil types, lighting, humidity, and other key factors, Artificial Intelligence is capable of creating highly personalized recommendations regarding the selection of optimal locations for planting vegetation, harmonious color schemes, and appropriate materials for paving and decoration. Taking into account a variety of factors, such as the microclimatic conditions of a specific site, soil type, terrain features, and even the site's orientation relative to the cardinal directions, AI ensures the most efficient use of every patch of space and creates the most appropriate and aesthetically appealing landscape design that corresponds to the conditions of a particular location. In addition to this, Artificial Intelligence has the capability to analyze data on previously implemented projects, obtaining valuable information about their effectiveness and identifying potential shortcomings. A thorough evaluation of the performance of past projects helps professionals avoid repeating typical mistakes, refine their professional skills, and constantly improve the quality of their work, learning from their own and collective experience. The application of Artificial Intelligence in garden design not only contributes to a substantial increase in the overall quality of projects and their functionality but also significantly saves valuable time and effort for professionals. This, in turn, frees them from routine tasks, allowing them to focus on developing unique creative concepts, searching for innovative design solutions, and on more fruitful interaction with clients to better understand their needs and preferences.

Artificial intelligence is fundamentally changing our perception of the conceptualization process in design, actively utilizing generative design. This innovative approach allows for the extremely rapid creation of a wide range of diverse design options, based on given initial parameters and clearly defined criteria. Such technology significantly simplifies the design process at the initial stages and opens up fundamentally new possibilities for creative exploration and experimentation with forms and space. In the future, Artificial Intelligence will even be able to conduct in-depth analysis of various ecological factors and predict potential changes in the landscape with high accuracy, which will undoubtedly contribute to more sustainable and highly effective planning of future garden and park areas, taking into account long-term perspectives. However, in the context of the rapid development of technologies, it is extremely important to constantly remember that unique human creativity and unparalleled aesthetic perception of the world still remain unsurpassed qualities that cannot be fully reproduced artificially. Therefore, despite the fact that the automation of many routine processes can greatly facilitate the work of a landscape designer, to achieve truly outstanding results and create masterpieces of landscape art, it is worth persistently striving for a harmonious combination of advanced digital tools with deep human professionalism, experience, and intuition. In the long run, the use of Artificial Intelligence for analyzing environmental factors and predicting landscape changes will enable the creation of even more sustainable and effective plans for garden areas. However, a key aspect, as before, remains unsurpassed human creativity and unique aesthetic vision. Thus, although automation greatly simplifies the tasks of landscape designers, achieving the best results requires a harmonious balance between the capabilities of digital technologies and irreplaceable human professionalism.

In the near future, we can with high probability expect the further active development of ecologically conscious and sustainable farming practices, driven by the progress and widespread adoption of Artificial Intelligence technologies. This includes a tangible improvement in existing methods for the rational management of natural resources, a deeper integration of environmental aspects and principles of sustainable development directly into the landscape design process, as well as a steady increase in the role of automated systems and intelligent automation in modern landscape design. The implementation of Artificial Intelligence in garden design practice is capable of providing a significant simplification of routine stages of the design process and, importantly, opening up opportunities for the generation of completely new, sometimes unpredictable, but always interesting and fresh design ideas. However, in the pursuit of technological progress, it is extremely important to constantly remember the need to find a reasonable balance between the effective use of advanced technologies and the careful preservation of unique human creative individuality and professional autonomy. In the long-term perspective, we can quite reasonably expect an even more intensive development of various sustainable practices, as well as an ever-increasing impact of Artificial Intelligence on the field of garden and park design. This, undoubtedly, will actively contribute to the creation of more environmentally friendly, harmonious, and aesthetically expressive garden spaces that will bring satisfaction to many generations. The gradual increase in the significance of Artificial Intelligence in garden design may also initiate qualitative changes in our perception of nature and ways of interacting with it, opening up new horizons for the harmonious coexistence of technology and natural ecosystems. Active use of automated irrigation and intelligent climate control systems is capable of effectively helping to maintain plant health and ensure optimal, scientifically sound use of valuable water resources, preventing their inefficient consumption. We can also quite reasonably expect the emergence of fundamentally new technological solutions that will allow for the creation of truly "smart" gardens of the future, where diverse plants will actively interact both with each other and directly with people and the surrounding environment, forming dynamic and interactive ecosystems. At the same time, it is extremely important to closely monitor that this rapid technological progress in no way disrupts the existing natural ecological balance and does not suppress the unique natural beauty and harmony of the surrounding garden spaces. Artificial Intelligence has significant potential to tangibly improve the quality of life for many people by ensuring a more sustainable and economically efficient use of limited natural resources. However, to guarantee the undeniable success of such innovative technologies in the field of garden design, it is necessary to take care in advance to carefully preserve the "human factor" in the creative process and the unique unpredictability of nature itself. It is precisely these factors that give unique individuality, special charm, and natural beauty to our beloved gardens, making them so attractive and valuable to us. Ultimately, finding the optimal balance between the capabilities of advanced technologies and the wisdom of nature itself is a key task for the further successful development of sustainable practices in garden design for the benefit of future generations.

Conclusions.

Artificial intelligence is currently enacting a veritable revolution in the field of landscape architecture, fundamentally altering traditional approaches and unveiling novel perspectives. Forging unprecedented opportunities for both pioneering design and the streamlined management and upkeep of diverse garden and park amenities. Cutting-edge Artificial Intelligence technologies unlock the subsequent capabilities:

- Generate innovative design solutions.
- Optimize resource usage.
- Increase the environmental sustainability of projects.
- Improve visitor experience.

Integrating AI into landscape design paves the way for creating "smart" green spaces that adapt to user needs and environmental changes.

Promising areas of development include:

- Development of specialized AI tools for landscape architects.
- Improving automated plant care systems.
- Creating personalized recommendations for visitors.
- Implementing predictive analytics for green space management.

Fruitful collaboration between humans and Artificial Intelligence in the field of landscape design establishes a truly unique symbiotic relationship, where advanced technologies act not as a replacement, but as a powerful tool for qualitative enhancement of the creative potential and long-standing professional expertise of specialists. This partnership actively shapes an entirely new era in the evolution of landscape art, where innovative technological solutions are employed to achieve a noble goal – the creation of harmonious, ecologically balanced, and sustainable green spaces of the future that will delight the eye and benefit many generations to come.

The future of the industry lies in the balance between technological capabilities and traditional approaches. The successful integration of AI into landscape design depends on the ability of professionals to adapt new technologies to existing practices, creating harmonious and functional spaces for future generations. The integration of artificial intelligence into landscape architecture can have a significant impact on the quality and sustainability of garden and park facilities. The use of AI helps to optimize design processes, while maintaining the designer's unique creative vision. In addition, artificial intelligence allows you to create personalized solutions that take into account local features and promote biodiversity. The use of AI also helps to efficiently use natural resources, making projects environmentally sustainable. In a practical sense, this means creating attractive and functional spaces that take into account the needs of the present and the future. Thus, artificial intelligence can become an indispensable assistant to landscape architects, contributing to the harmonious development of man and nature. The application of this technology in landscape design is proving to be a powerful tool for achieving a balance between functionality, aesthetics and environmental sustainability of projects. It is important to note that the successful implementation of AI in this industry requires ongoing professional development and attention to the ethical aspects of the use of artificial intelligence. All this can be a key factor in ensuring the quality, efficiency and aesthetic appeal of projects. Therefore, the use of artificial intelligence in landscape design not only speeds up and facilitates the work of the designer, but also helps to create a truly living and balanced space for the future.

REFERENCES

1. International scientific conference "MININGMETALTECH 2023 – The mining and metals sector: integration of business, technology and education": conference proceedings (November 29–30, 2023. Riga, the Republic of Latvia). Riga, Latvia : "Baltija Publishing", 2023. Vol. 2. 348 P.
2. IX International scientific and practical conference "Scientific Problems and Options for Their Solution" (February 7-9, 2024) Bucharest, Romania, International Scientific Unity. 2024. 310 P.
3. Information technologies in the field of environmental protection: materials of the International Scientific and Practical Conference, May 16–17, 2024 – Educational and Scientific Institute of Spatial Planning and Advanced Technologies of the National University "Lviv Polytechnic". – Lviv: Lviv Polytechnic Publishing House, 2024.
4. Barbarash, D., Rasheed, M., & Gupta, A. (2022). Automated Recording of Human Movement Using an Artificial Intelligence Identification and Mapping System. Journal of Digital Landscape Architecture. https://doi.org/10.14627/537724007
5. Hurkxkens, I., Fahmi, F., & Mirjan, A. (2022). Robotic Landscapes: Designing the Unfinished. Park Books.
6. Liu, X., & Tian, R. (2022). RiverGAN: Fluvial Landform Generation Based on Physical Simulations and Generative Adversarial Network. Journal of Digital Landscape Architecture.https://doi.org/10.14627/537724011
7. Raman, TA, Kollar, J., & Penman, S. (2022). Chapter 17 - SASAKI: Filling the design gap—Urban impressions with AI. In I. As, P. Basu, & P. Talwar (Eds.), Artificial Intelligence in Urban Planning and Design. PP. 339–362. https://doi.org/10.1016/B978-0-12-823941-4.00002-0
8. Suppakittpaisarn, P., Lu, Y., Jiang, B., & Slavenas, M. (2022). How do computers see landscapes? Comparisons of eye-level greenery assessments between computer and human perceptions. Landscape and Urban Planning, 227, 104547.https://doi.org/10.1016/j.landurbplan.2022.104547
9. Narumali, Kaveri & Saraswati, Shwetha & Naik, Praveen. (2025). Use of artificial intelligence in landscape design and maintenance. URL: https://www.researchgate.net/publication/387721832_USE_OF_ARTIFICIAL_INTELLIGENCE_IN_LANDSCAPE_DESIGN_AND_MAINTENANCE

MONITORING OF TREES DETERIORATION FACTORS IN THE URBAN CENOSES OF ZHYTOMYR CITY

Andreieva Olena
Doctor of Agricultural Sciences, Associate Professor, Polissia National University, Ukraine
ORCID ID: 0000-0003-0851-800X

Shvets Maryna
Ph.D. in Biological Sciences, Associate Professor, Polissia National University, Ukraine
ORCID ID: 0000-0002-1116-3986

Martynchuk Ivan
Ph.D. in Economics, Associate Professor, Polissia National University, Ukraine
ORCID ID: 0000-0002-1370-677X

Marchuk Danylo
Post-Graduate Student, Polissia National University, Ukraine
ORCID ID: 0009-0000-8503-6835

Introduction.

Urban green spaces perform important ecological functions, but at the same time, they are more vulnerable than forests to any adverse factors, in particular to insect damage [11, 15]. Their condition has recently deteriorated, primarily due to climate change and anthropogenic load [5, 8, 9, 23]. Since the air temperature in the city is higher than in the forest, insects have the opportunity to develop faster, produce more generations, and cause more damage to trees [16]. In Zhytomyr, green spaces grow in parks, on the territories of enterprises, and on the streets [24, 26]. In many regions, alien or adventitious species of phytophagous insects have penetrated green spaces, which have found better conditions for development and wintering in the city than in the forest [40–42]. The most resistant to man-made pollution and common in urban green spaces are insects that develop inside leaves, in particular, the so-called leaf miners. Prevention of the harmful effects of leaf miners should be based on the study of the features of their distribution and biology. Insects that develop inside leaves, in particular, the so-called miner insects [43–46], are the most resistant to man-made pollution and are widespread in green areas of cities. Prevention of the harmful effects of mining insects should be based on the study of the peculiarities of their distribution and biology.

1.1. General characteristics of the research region and research methodology

The city of Zhytomyr was founded 1130 years ago. It is located at an altitude of 220–240 m above sea level with a surface slope in the northeast direction. The city is surrounded by forests, the Teteriv River flows through it. The relief is a slightly undulating plain, among which there are large, rounded moraine hills with long, gentle slopes. The soil cover is mainly represented by sod-podzolic soils of varying degrees of podzolization and granulometric composition. The most common are sandy and clay-sandy, sod-weakly podzolic soils.

The city is located in a zone of humid continental climate with warm and humid summers and mild winters. The average annual air temperature is +7.2°C; the average temperature in January is -4.4°C, and in July, it is +17.8°C. The last spring frosts are recorded in the third decade of May, the latest in the first half of June, and the first autumn in the second decade of September. The duration of the frost-free period is 150–170 days. The snow cover is uniform (10–20 cm) and lasts for 95–110 days but is unstable due to frequent thaws. The average height of the snow cover in December is 2.3 cm, in January – 6.4 cm, in February – 8.4 cm, and in March – 4.3 cm. The average date of formation of a stable snow cover is December 15, and its destruction is March 9.

During the year, 530–600 mm of precipitation falls, of which 40–45% falls in the summer months. The amount of precipitation in individual years has significant deviations: in some rainy years, it can fall up to 1000 mm, and in dry years, only 300 mm. The maximum amount of precipitation falls in June (61–106 mm) and July (76–106 mm). The region is dominated by northwesterly winds. In general, the climatic conditions of the city are favorable for the growth and development of plants. A comparison of data on air temperature and precipitation for 2020 and multi-year data for 1990–2019 shows that in 2020, the amount of precipitation was inferior to the multi-year data in most months and slightly exceeded them only in May and June. We calculated that the air temperature, on the contrary, exceeded the multi-year data in most months and was slightly lower than them only in April and May. The average air temperature for the growing season of 2020 was 16.7°C, which exceeded the multi-year data (15.8°C) by 0.9°C (Table 1).

The sum of temperatures during the growing season in 2020 exceeded this indicator for 1990–2023 by 158.8°C, and the amount of precipitation in 2020 was 107.4 mm lower than long-term data (Fig. 2.1). As a result of such changes, the hydrothermal coefficient according to G.T. Selyaninov (HTC) decreased from 1.28 according to long-term data to 0.86 in 2020, i.e. by 0.4. These changes are not beneficial for vegetation.

Table 1. Weather conditions in 2020 and their deviations from multi-year data for 1990–2019 (Zhytomyr weather station)

	Precipitation, mm		**T °C**		**Sum for IV–IX, T °C**		**Deviation**	
Months	**2020 year**	**1990–2019**	**2020 year**	**1990–2019**	**2020 year**	**1990–2019**	**precipitation, mm**	**T °C**
I	18	31,6	1,0	-3,9	–	–	-13,6	4,9
II	48	29,7	3,0	-2,6	–	–	18,3	5,6
III	18	33,8	6,0	2,1	–	–	-15,8	3,9
IV	23	38,6	9,0	9,3	270	279	-15,6	-0,3
V	59	58,5	12,0	14,4	372	446,4	0,5	-2,4
VI	77	74,6	20,0	18,3	600	549	2,4	1,7
VII	42	80,6	20,0	19,4	620	601,4	-38,6	0,6
VIII	24	59,2	21,0	19,4	651	601,4	-35,2	1,6
IX	39	59,9	18,0	13,9	540	417	-20,9	4,1
X	70	40,5	13,0	8,1	–	–	29,5	4,9
IV–IX	264	371,4	16,7	15,8	3053	2894,2	–	–

Many species of trees and shrubs grow in parks and street plantings in Zhytomyr. Since the city is surrounded by forests, some old trees have been growing in the city since ancient times. Planned landscaping is carried out in parks and new districts. Since industrial enterprises operate in Zhytomyr and highways and railways pass through the city, connecting Kyiv with many western regions, the city has a high anthropogenic load. Atmospheric air and soils contain heavy metals, salts, and residues from the activities of enterprises and vehicles, which negatively affect woody plants.

The research was conducted in Shoduarivskyi Park, and 30-richchia Peremohy, on the streets of the center – Peremohy St., Kyivska, and Velyka Berdychivska St., as well as on the streets of the industrial zone – Koroliova and Paradzhanova.

Starting from the 1st decade of May, 100 leaves were picked every decade, randomly selected from trees of each species and placed in separate bags with labels. During the office processing of the research material, the number of mines, pupae, larvae, and exuviae of miners on each leaf was determined [23, 27]. The density of mines of each insect species was calculated per leaf. The population of each species was determined as the average proportion of leaves with the presence of mines.

Statistical analysis of data was carried out using the MS Excel software package.

1.2. Anthropogenic factors in urban ecosystems

Under the influence of man, the Earth's natural ecosystems are transformed into agrobiocenoses, urban ecosystems, and technocenoses [15]. Agrobiocenoses, or agrocenoses (from the Greek agros - field), are created and maintained by man for the production of agricultural products. These are fields, vegetable gardens, orchards, vineyards, meadows, etc. Technocenoses are ecosystems under the influence of industrial facilities. Urban ecosystems (from the Latin urban - urban) are ecosystems under urban conditions. Urban ecosystems include architectural and construction facilities (industrial and residential buildings, communications, etc.), artificial landscapes, and disturbed natural ecosystems (parks, gardens, etc.). Unlike natural ecosystems, urban ecosystems are incapable of self-regulation. The natural heterogeneity of the environment, which was originally of natural origin, changes to zonal heterogeneity of anthropogenic origin, which often has a concentric type (from the periphery to the center) [15].

Green spaces in cities are designed to create optimal conditions for work and recreation for the population, as they can purify the air from dust and emissions from industrial enterprises and vehicles, reduce noise levels, improve the microclimate (reduce temperature through transpiration, enrich the atmosphere with oxygen, protect from wind), emit phytoncides, and also have a positive effect on the human nervous system [16]. At the same time, such spaces are weakened by the aforementioned emissions, dust, etc., and become vulnerable to pests and pathogens, in particular to alien species [20]. Trees are also weakened due to insufficient area for root development and their destruction during the construction and repair of roads and communications.

Dust and moisture form fog, which prevents the respiration and photosynthesis of leaves. The air temperature in the center of cities is several degrees higher than in the forest, which affects the rate of development of insects and the attractiveness of the leaves for their nutrition [21].

Urban plantings feature tree species that grow in forests and gardens of the region but also use introduced species due to their decorativeness or resistance in urban environments [15]. Trees in urban plantings, like in the forest, produce oxygen and emit phytoncides, and also capture dust and toxic substances from the air, soften the microclimate, and improve people's moods [16].

At the same time, trees grow in the city in conditions of increased temperature since brick, concrete, and asphalt heat up during the summer and cool down slowly. In winter, the central heating system of houses operates, which also contributes to an increase in temperature compared to its values outside the city. Temperature changes affect the timing and rate of development of buds, shoots, and leaves in spring, flowering, and fruiting, as well as the success of preparing trees for winter [21]. Increased temperature also affects the phytophagous insects and pathogens of tree species. These organisms accelerate development in conditions of increased temperature, which can affect their harmfulness. At the same time, both trees and their pests and pathogens suffer from air pollution, and the consequences of their interaction are not always predictable [22].

The main sources of air pollution in cities are industry and vehicles, and the role of the latter has recently increased. Typically, individual districts and streets of cities differ in the intensity of traffic, which is determined by the average number of cars and trucks per day. Transport emissions negatively affect the condition of trees in green spaces of cities, and the most sensitive tree species can serve as indicators of air pollution [2–4].

In urban conditions, trees quite often receive mechanical injuries during construction and repair work, as well as due to vandalism by residents. Through the places of such injuries, as well as in frost cracks and occasionally - in places where lightning strikes, wood-destroying fungi - pathogens of rot, gradually destroy individual parts of the trunks [13]. If such fungi destroy the core of a tree, it can remain viable for many years and have a healthy-looking crown. At the same time, trees that have been affected by wood-destroying fungi for a long time can be very dangerous for people and vehicles in the event of strong winds, which lead to the breaking off of individual branches or even the tops or part of the trunk [12].

In the conditions of settlements with strong human intervention in the composition of the soil and water regime, factors of negative action increase their impact [25, 26]. The composition of the soil in cities differs from that of forests, it contains many fragments of building materials covered with asphalt. The place for root growth is limited [15].

The city is characterized by specific microclimate, light and wind regimes, gas composition of the air, etc. [21]. In the city, there is less penetration of ultraviolet radiation, lower relative humidity, and more frequent fogs. Due to lower atmospheric pressure and wind speed, air pollution increases [20].

Building surfaces and road surfaces heat up more intensively during the day and give off heat more slowly at night than soil or topsoil in rural areas. The increase in air temperature is contributed by the activities of industrial enterprises, vehicles, and the heating of buildings [15].

The air temperature is several degrees higher in the city center than on the periphery and beyond [15]. This affects the timing of the beginning and end of vegetation, in particular, leaf development. With increasing temperature and dryness of the air, burns form on the leaves of trees, which reduces the surface area capable of photosynthesis.

Trees in the city receive mechanical damage during construction and repair work, as well as as a result of injury by vehicles and the population. Pathogens penetrate places of mechanical damage. Injury to the roots and trunk creates conditions for the settlement of trees by harmful insects [24, 28].

One of the important factors of negative anthropogenic impact on the environment in general and on green spaces in particular is the exhaust gases of motor vehicles. At the same time, the highest concentrations of harmful substances are observed near large settlements. It has been proven that the concentrations of pollutants decrease at a distance of 12–20 m from the road, and in densely built-up areas, the concentration of pollutants is much higher than in open areas [26].

The number of motor vehicles is steadily increasing, despite the increase in fuel prices. Motor vehicles pollute the atmospheric air of cities and negatively affect human health and the condition of green spaces, which are unable to compensate for these negative effects. It is estimated that the volume of emissions of harmful substances from motor vehicles is almost three times higher than the volume of emissions from stationary sources of pollution [25].

1.3. Biotic factors influencing the condition of stands in urban ecosystems

Biotic factors influencing trees are associated with plants that compete for moisture and soil nutrients, with vertebrate and invertebrate phytophagous animals and phytopathogenic organisms, in particular bacteria, viruses, and fungi [27]. In general, trees in the city can be damaged by mammals, birds, ticks, and insects and be affected by viral, fungal, and bacterial diseases [1, 5–7]. At the same time, the distribution of various types of damage in urban green spaces and the harmfulness of these species differs from forest ecosystems.

The entomofauna of urban plantings was initially formed mainly due to the penetration of species from neighboring forests and gardens [10–11]. Recently, its composition has been changing due to an increase in the proportion of representatives of ecological groups of insects that are resistant to technogenic pollution, dust, and temperature fluctuations [41], in particular, miners [44]. The species composition of the entomofauna of urban plantations is also replenished due to the penetration of adventitious species with plant material and packaging, which find attractive food species and favorable conditions for survival in the winter [39, 43].

1.3.1. Phytophagous insects. Insects that damage leaves are called phyllophage

These insects can have an open, semi-hidden, or hidden lifestyle [14, 18, 19]. An open lifestyle is characterized by species with both gnawing and sucking mouthparts. Lepidoptera and hymenoptera larvae, adults and larvae of coleopterans have gnawing mouthparts, with which they eat and skeletonize leaves. Larvae and adults of representatives with a piercing-sucking mouthpart (bugs, aphids) suck plant juices. The latter species are less directly affected by pollutants. A hidden lifestyle is characterized by miners (which have gnawing mouthparts) and gall-formers (which may have gnawing or sucking mouthparts). As a result of the miners' feeding, a cavity is formed in the leaf tissues, and as a result of the gall-forming insects' feeding, the plant tissues grow, and galls are formed. Insects that develop inside rolled, glued, or woven leaves have a semi-hidden lifestyle.

Leaf-eating insects, while on or in leaves, cause various types of damage, by which they can be recognized even after the insects have left their feeding sites [38, 42]. Damage caused by leaf miners and gall-forming insects is particularly characteristic, but the feeding traces of species with an open lifestyle also allow us to estimate their prevalence in different parts of the stand. Thus, leaves may be partially eaten away, skeletonized, holes or cuts of almost regular shape may be gnawed in the middle or from the edges, small holes, and leaf tissues may be scraped off [44]. Therefore, the proportion of the removed leaf area indirectly reflects the number of leaf-eating insects with a certain type of feeding [40].

Mass reproduction of leaf-eating insects in cities occurs relatively rarely, but individual trees may be noticeably damaged by leaf miners, leaf eaters or leaf gnawers [32, 37]. According to their ability to form outbreaks of mass reproduction, phytophagous insects are divided into indifferent, prodromal, and eruptive species [23]. Thus, the number of indifferent species in long-term dynamics varies slightly relative to the background level. Prodromal and eruptive species are capable of repeatedly increasing their number, which fluctuates in prodromal species near the lower stationary level, and in eruptive species it can remain at the level of the upper stationary level of the phase portrait for several generations without losing the ability to regulate the population size [8, 9].

It is believed that leaf damage by insects negatively affects the growth and fruiting of stands [34]. At the same time, unlike forests, in urban plantations, the main criterion for assessing the harmfulness of phyllophages should be the impact not on tree growth but on the loss of the trees' ability to purify the air and decorate. If the plantation has lost these characteristics, then its durability and fruiting intensity are of less importance [15].

It is believed that deciduous trees can withstand the loss of up to 30% of their leaves without losing their viability and growth intensity [47]. Thus, losses are determined only during outbreaks of mass reproduction of individual insect species, which occur once every 10–12 years. In general, to determine the number of phyllophage insects of a certain species or group, their limiting number is calculated by dividing the mass of leaves on a tree of a certain species and age by the larval food norm. At the same time, a tree weakened by adverse factors contains fewer leaves, and its severe damage can be caused by fewer insects [40]. The harmfulness of any insect species depends on its ability to damage the plant during feeding, negatively affect the environment, and form outbreaks of mass reproduction (such as population dynamics) [38].

In parks and forest parks created based on former forest areas, the phytophagous complex is the most diverse and includes phyllophages, miners, sucking insects, gall-forming insects, and xylophagous insects [29, 30]. In street stands, the insect complex is the poorest. The above-ground part of trees growing near roads is openwork, blown and exposed to atmospheric pollutants and powerful wind currents from traffic. Under such conditions, a complex of insects adapted to the action of adverse factors is formed. These are species that are mechanically protected by waxy covers - coccidia, leaf epidermis - miners, as well as species that compensate for increased mortality with high fecundity and a large number of generations per year – aphids, spider mites, etc. [27].

Insects adapt to climate change faster than trees since they have shorter life cycles. If the leaves are not sufficiently moistened, leaf eaters will destroy a larger mass of them [40].

An additional threat to urban plantings in new ecological conditions may be alien (adventitious) species that penetrate urban stands with packaging, planting material, seeds, soil, and on vehicles [36].

Changes in urban ecosystems can be detected by monitoring and bioindication – recording the reaction of living organisms to different levels of anthropogenic load. In this case, species and complexes of species that are widespread and easily detected are used, in particular, turunas, gall-forming insects, and miners [31, 35].

The species composition of insects and mites – phytophagous insects of urban stands is generally similar to that of the surrounding forests. These species feed on various organs of trees – leaves, buds, generative organs, damage, and colonize roots and trunks [33].

At the same time, some species cannot withstand the effects of elevated temperatures or harmful impurities in the air [47]. In urban stands, leaves are removed for the winter, which makes it impossible for some phytophagous and entomophagous insects to overwinter. Some species are unable to feed on dust-covered leaves, or it has a toxic effect on them. In urban conditions, the proportion of small-sized species with sucking mouthparts and a secretive lifestyle – miners and gall-forming insects – increases [38].

In cities, spring begins earlier than in the forest or field, autumn comes later, and the air temperature is higher [15]. Therefore, polyvoltine insects in urban conditions have a larger number of generations and are able to further increase their numbers. At the same time, insects also do not always withstand the effects of polluted air, and in urban conditions, outbreaks of mass reproduction develop very rarely [27].

Pollution of plants by industrial and transport emissions affects the chemical composition of leaves, the overall resistance of plants, and their resistance to insect damage [15]. In cities, the soil is compacted, and therefore, insects that do not depend on it for development have an advantage [28]. In urban stands, phytophagous, leading a secretive lifestyle, and insects with a prickly-sucking mouthparts [11] predominate. In particular, miners and gall-forming insects have a secretive lifestyle, and representatives of various ecological groups of insects have a semi-secretive lifestyle. Miners are known among lepidopterans, beetles, hemi-beetles, and dipterans. Galls on various plant organs can be formed by mites and insects, in particular, dipterans, aphids, and even beetles. Bedbugs and aphids have prickly-sucking mouthparts [10].

Species with a semi-hidden lifestyle include leafhoppers, whose caterpillars roll up leaves and feed inside. Tubeworms roll up a leaf and lay an egg inside to provide the larvae with food - a dried leaf [27]. Insects that feed inside plant tissues are provided with a relatively constant humidity regime, protected from extremely high temperatures, and due to the high thermal conductivity of leaf tissues, from low temperatures. Such insects are less sensitive to abiotic factors in air pollutants [1].

The species composition of the phytophagous in the city is quite rich, but their number rarely reaches the level of that in the forest [23]. Dozens of species of insects and mites feed on various organs of trees, but not all of them are pests. Harmful species are those whose damage leads to a decrease in the viability or death of trees. Typically, a tree can withstand damage of up to 30% of the leaf mass and compensate for it during further development [40].

The appearance of the damage often identifies the order, family, and sometimes the species of the pest. For example, leafhoppers weave silk threads that they produce and form a shelter. Some larvae or adults skeletonize the leaves. The larvae of butterflies, sawflies, and occasionally beetles bore holes in the leaves. Sucking insects - aphids, scale insects, and leafhoppers feed on the sap of poplars [27].

Gall-forming organisms live inside the tissues of poplars and form galls on branches, shoots, petioles, and leaves. Younger insects live in the galls, which provide food and protection from natural enemies. Galls are formed by some mites (Acari), butterflies (Lepidoptera), sawflies (Hymenoptera), aphids, bedbugs (Hemiptera), and flies (Diptera). Galls can be simple or complex, and it is often possible to recognize the insect by their appearance [27].

Buds and young shoots damage the leaves. Some beetles eat the entire buds, and other species lay eggs in them. The larvae feed inside, and then the bud falls off. Glassworms and some barbels gnaw through the passages in the shoots of poplars [7]. As a result, young plants develop several tops. The decorative value of the trees and the commercial value of the wood decrease. Rot pathogens penetrate the trunk. The roots of trees are damaged by beetle larvae, as well as some trunk pests - glassworms and woodworms [30].

As trees grow, a complex of stem pests is formed, which are confined to certain areas of the bark or parts of the tree [44]. These species, like most stem insects, can actively or passively transmit spores of pathogenic, wood-staining, and wood-destroying fungi, in particular blue mold.

Close attention to the study of insect communities in green spaces began to be paid in the middle of the last century in connection with the emergence of large industrial zones [18, 19]. Such studies were aimed at determining the minimum size of a green area at different levels of pollution and the minimum size of individual plantings that would positively affect the environment and maintain the resistance of this environment to negative influences.

Insect miners feed inside plant tissues that are the most humid, rich in nutrients, and poor in protective substances [47]. This lifestyle protects these insects from moisture deficiency and natural enemies and allows them to overcome plant defenses. Insect miners are highly specific to specific plant organs and tissues [1]. Miners spread to new regions along with planting material and packaging [47]. They are more easily established in urban areas than in forest stands since cities have a greater selection of attractive forage species, and elevated air temperatures facilitate insect survival in winter [15].

Typically, most phyllophage insects do not cause significant damage to urban stands, but the negative impact of individual insect species on the condition of trees weakened in urban conditions may increase in years of mass reproduction outbreaks [47]. Since both the anthropogenic load and the species composition of phyllophage insects differ in urban stands of different types [10], it is advisable to compare the species composition and distribution of these species in street stands, parks, and the Forest Park.

1.3.2. Urban green spaces as a medium for the spread of harmful insects

Urban green spaces are a collection of woody, shrubby, and herbaceous plants that form arrays, alleys, lawns, and flower beds in parks, squares, on the sides of sidewalks, in the courtyards of the private sector, enterprises, educational and medical institutions, etc. [2].

Urban green spaces are created not only to perform a recreational function. These stands absorb air pollutants (dust, gases, etc.), cool the urban environment, stabilize the wind regime, increase the relative humidity of the air and mitigate its daily and seasonal fluctuations, enrich the atmosphere with oxygen, increase the concentration of negatively charged ions in the atmosphere, secrete biologically active substances that suppress pathogenic microflora in the atmosphere, reduce the noise level by absorbing mechanical vibrations, retain part of the precipitation and reduce surface runoff, improve soil structure, retain snow cover and melt water, consolidate loose soils and reduce the level of erosion, and improve the appearance of urban landscapes [17].

Therefore, when selecting plants for parks, it is necessary to take into account their ability to withstand cultivation in a wide range of soil mechanical composition and richness, their tolerance to moisture conditions, resistance to industrial gas and aerosol pollution, absorption of pollutants from the atmosphere or soil, the presence of a branched crown with dense foliage for effective noise absorption, aesthetic properties, etc. [30, 36]. At the same time, urban green spaces are weakened by pollutants and are more susceptible to damage by insects [27]. There is almost no vegetation in the city on which entomophagous insects can provide additional nutrition.

The presence of houses, fences, utility rooms, and other structures provides conditions for the successful wintering of harmful insects, which contributes to the growth of their numbers in cities [18]. Trees in cities have sparser crowns and smaller leaves compared to forest trees. Leaves covered with dust reduce the intensity of photosynthesis. Under such conditions, damage to leaves by insects in cities can have more significant consequences for the viability of trees [22]. In cities, leaf-mining insects are more common than in forests, which are characterized by a secretive lifestyle and are therefore more resistant to adverse weather factors and air pollutants than leaf-borers [14].

In the context of climate change, urban stands may suffer primarily because non-native species are often used in landscaping, as well as with faster climate changes in cities, where stone, concrete and brick buildings and road surfaces are heated more strongly by sunlight and give off heat more slowly than soil or topsoil in rural areas. Temperatures also rise as a result of industrial activities, vehicle engines, and the heating of buildings [17].

Weakened trees become susceptible to insect infestation or disease. Increased air temperature accelerates the development of trees and pests, and insects adapt more quickly to new conditions since they have one or more generations per year. New climatic conditions may unexpectedly become favorable for previously inactive pests [14].

The entomofauna of urban stands is very similar to the entomofauna of neighboring forests [17], but has differences related to the characteristics of the urban climate, soil cover, and gas composition in the air. Since it is warmer in cities, insects that can develop in several generations additionally increase their numbers. Under the influence of technogenic emissions, the chemical composition of leaves, plant resistance, and their resistance to insect damage change. Since the soil in cities is compacted, insects that do not depend on it for development have advantages [36]. In urban stands, phytophagous insects that lead a secretive lifestyle and insects with a prickly-sucking mouthparts predominate [10].

Alien species of phytophagous insects have advantages over local ones due to the lack of specialized entomophagous insects. Introduced species can affect community structure, biodiversity, food chains, and overall ecosystem productivity [14, 22].

1.3.3. Insect miners of deciduous trees in green stands

Insect miners develop inside plant organs or parts and gnaw holes, or “mines” in them [1]. Miners are known among representatives of the orders Lepidoptera, Hymenoptera, Diptera, and Coleoptera. The population density of many miners varies little over the years, and they do not cause harm to forage plants [39]. Some species are capable of mass reproduction, in particular, the chestnut miner (Cameraria ohridella Deschka & Dimic, 1986) [43] and the poplar lower leaf moth (Phyllonorycter populifoliella (Treitschke, 1833)) [19]. Other species, even at low population densities, can significantly reduce the decorativeness and resistance of individual trees and stands [1].

Larvae of obligate miners carry out the entire larval development cycle inside the mine, while facultative ones do so only for several instars. In all cases, the first larval instars pass inside the plant tissues [8]. Most often, miners damage species of the same or similar genera of woody plants, which have the corresponding names - “poplar”, “maple”, “willow” [11]. One larva develops in each mine, and in the case of merging mines, the youngest larvae die. At the same time, the larvae of some species can develop several individuals in one mine [23].

Miners most often pupate outside the mine, although some species can pupate in the first generation outside the mine, and in the second – in mines, and others – pupate both inside the mine and outside it [43].

Miners mainly overwinter as pupae, but some overwinter as larvae on the soil surface, in leaf sheaths on branches, in mines in fallen leaves, or as adults in bark cracks on tree trunks. In the pupal stage, miners can overwinter in the soil, in mines in fallen leaves, or bark cracks on tree trunks [39].

The number of generations of mining insects depends mainly on the ambient temperature [43].

Some species of leaf miners feed only in spring or early summer, others only in summer (birch leaf miners, linden leaf miners, and elm leaf miners). At the same time, some species have two or more generations (linden leaf miners and chestnut leaf miners) or an extended development period and feed throughout the season [23].

Leaf miners can be transported by air currents, and therefore, the centers of their mass reproduction are often located along transport routes [26].

Female leaf miners lay mainly one egg per leaf, which eliminates competition between larvae of one species for food [39].

Among the factors of leaf miner population dynamics, competition between individuals of the same population and with other species of phytophagous insects, as well as food quality, the effect of pathogens, predators, and parasitoids [14] are important.

Abiotic factors are mainly manifested in the form of destruction of mines under the influence of wind and precipitation and the effect of frost on the viability of miners at different stages of development. In the case of a decrease in temperature, the synchrony of the development of miner larvae and the availability of suitable food may be disrupted. In the case of rapid coarsening of leaf tissues, younger larvae are unable to consume them [39]. Most often, abiotic conditions create the prerequisites for the emergence of miner foci due to the positive effect on the viability of these insects. If the growing season is prolonged, the last generation of miners has time to complete its development [23]. Since the food base of miners on a tree depends on the available mass of leaves, an increase in the density of settlements causes competition, an increase in larval waste, and a decrease in the mass of pupae, size, and fecundity of adults [1]. If the mass of the leaf is not enough to complete the feeding of the larva, it dies. The larva will also die if the leaves fall prematurely [39]. Among the miners, mono- and oligophagous ones prevail – species that feed on one or several plant species [23].

According to the nature of damage to the leaf tissues, mines are divided into 4 types. In the first mines, the leaf parenchyma is completely eaten away, but the upper and lower epidermis are not damaged. If the palisade parenchyma is damaged, the mines are classified as upper-lateral, and if the spongy parenchyma is damaged, as lower-lateral. In the latter case, only the epidermis of the leaf is damaged - then the mine belongs to the epidermal type. The depth and shape of the mines depend on the insect species [1].

Insect miners develop much faster than insects with a free lifestyle. This is due to the fact that miners use leaf tissues that are easily digested and leave the epidermis, cuticle, and vascular bundle tissues. Caterpillars are able to develop only in tissues with a low content of protective substances [39]. Only some miners feed at the imago stage. Females select egg-laying sites based on chemical cues released by the plant, choosing leaves of a specific age and leaf blade size [23].

Adventitious species of mole miners can be dangerous because they have no natural enemies in a new place. The most well-known representatives of adventitious species of mole-miners are the *Phyllonorycter issikii* Kumata, *Cameraria ohridella* Desc, *Parectopa robiniella* Clemens, *Macrosaccus robiniella* Clemens, and *Phyllonorycter platani* Staud. [14, 23].

The chestnut miner damages the common chestnut (*Aesculus hippocastanum* L.), which is common in natural forests in the Balkans and is used for landscaping settlements throughout Europe. In western Ukraine, the chestnut miner appeared in 1996–1997, in 2003 in Kyiv, and in 2006 in Kharkiv [23].

The chestnut miner overwinters as a pupa in mines inside fallen leaves. The moths emerge in late April - early May and lay eggs on bitter chestnut leaves. The larva develops for 25–36 days, pupating inside the mine. In different regions, there are 2–4 generations per year [27].

Two species of miners develop on the *Robinia pseudoacacia* L. – the *Parectopa robiniella* and the *Macrosaccus robiniella*. Both species have several generations per year, which overlap. They overwinter in the pupal stage. They fly out in the third decade of May, during the development of the leaves [46]. The linden miner spread in the 80s of the last century in the European part of the former USSR and the 90s in European countries. The linden miner overwinters in the adult stage in cracks in the bark of linden trees. Females lay eggs one by one on the lower surface of linden leaves, which by that time have fully bloomed. After 10–14 days (in early June), the mines appear. After the development is complete, the caterpillars pupate in mines, usually in late June. After 7–9 days (in early July), the new generation of butterflies emerges, mates, and lays eggs on leaves. The second generation caterpillars develop in August, pupate in late August, and in September, the pupae emerge as adults that overwinter [12–13].

In the first generation, chestnut, lime, and acacia miners do not cause much damage to trees. According to data from many regions, the chestnut miner damages 1% of the leaf surface in June and over

60% in September [14]. As leaf mines develop, the surface area involved in photosynthesis decreases. Trees reduce productivity, and leaves lose the ability to fully perform ecological functions in green areas of cities - to retain dust and atmospheric emissions [17]. In the presence of a large number of mines, the decorativeness of trees decreases, their susceptibility to the penetration of pathogens increases, and leaves often fall prematurely [8]. So important pathogens of common bitter chestnut are the fungi *Guignardia aesculi* and *Erysiphe flexuosa,* which originate from North America. These fungi cause leaf necrosis, which in appearance resembles damage caused by miners. At the same time, chestnut leaf miner-butterflies lay fewer eggs on leaves affected by these fungi [44].

At high densities of insect miners, infested leaves reduce photosynthetic activity. At the same time, photosynthesis continues in the uninhabited parts of the leaves, and the anatomy of the veins is preserved even with the presence of more than 90% of the mines [11]. Trees damaged by insect miners often re-bloom in late summer or autumn. This weakens the trees, they do not have the opportunity to prepare for the winter cold and often freeze out. In the spring, individual branches of such trees dry out, they are affected by diseases. At the same time, in the southern regions, damage to chestnut trees by the chestnut miner for several years did not cause mass tree loss and did not hurt annual wood growth [8]. This reaction of the common bitter chestnut tree to damage by the chestnut miner is explained by the ability of this species to form additional layers of wood with large openings in the conductive tissue during the year. Trees severely damaged by the chestnut miner begin growing later in the following spring, which may to some extent protect them from attacks by harmful insects [10].

The effect of miners on the generative organs of damaged bitter chestnut trees was also studied. It was found that in trees with severely damaged leaves, the size and weight of the fruits decrease, but the number of inflorescences on the tree, flowers in the inflorescence, and seeds in the fruit does not change. In urban stands, such a phenomenon is not significant, but in natural forests, it will negatively affect the restoration of bitter chestnut and will also not allow obtaining planting material for landscaping of high quality and in sufficient quantity [8].

The effect of the linden miner on the productive and generative organs of the small-leaved linden in the Forest-Steppe was quantitatively assessed [4]. It was found that the linden miner causes the greatest damage in June, during the growth period of the host tree. With a high density of the miner settlement, the number of flowers and inflorescences decreases, which causes damage to beekeeping in the region. It has been proven that the density of lime tree leaf miners increases in shaded areas. The undergrowth, lower crown tiers, and parts of branches at the base are most populated [13]. Since light leaves play a greater role in photosynthesis than shade leaves, damage to trees by lime tree leaf miners may not have noticeable consequences for productivity. At the same time, at high mine densities, a decrease in shoot length, the number of formed buds, and the growth of early wood were noted [12]. Thus, in urban green spaces, leaf miners are spreading, which worsens the sanitary condition of the plantings and their decorativeness. To prevent the damage that these insects cause, it is necessary to clarify the features of the development and distribution of the most dangerous species.

1.3.4. Pathogens of tree diseases

Foliar diseases usually do not cause deterioration of the condition of trees, in particular spotting [33]. Branches are affected by necrotic-cancer diseases. As the age of trees increases, the prevalence of stem rots increases, which are caused by fungi, in particular, *Polyporus squamosus* (Huds.) Fr., *Stereum rugosum* Pers., *Lenzites betulina* (L.) Fr., *Fomitiporia punctata* (P. Karst.), *Laetiporus sulphureus* (Bull.) Murrill. Brown central destructive rot is caused by the woolly scale fungus (*Pholiota squarrosa* (Oeder) Kumm: Stophariaceae) and the fatty scale fungus (*Pholiota adiposa* Fr.), white peripheral rot by the woolly stereum (*Stereum hirsutrum* (Willd.) Pers.: Stereaceae), white mixed corrosive rot by the common tinder fungus (*Fomes fomentarius* (L.) Gill.: Polyporaceae), and white corrosive central rot by the scaly tinder fungus (*Polyporus squamosus* (Hudz.: Fr.)) and the false tinder fungus (*Phellinus igniarius* (L.) Quel: Hymenochaetaceae) [44].

Recently, a disease called chalaro necrosis, caused by the fungus *Hymenoscyphus fraxineus* [36], has spread throughout the entire range of common ash. Signs of the disease have been registered in Ukraine since 2010. Symptoms of the disease include gradual dieback of crowns, necrotic spots on the bark of shoots, discoloration of wood and leaves, leaf necrosis, premature leaf fall, trunk necrosis, etc. Other important diseases of ash trees are bacterial blight (causative agent: *Erwinia amylovora* (Buril) Winslow et al.), bacterial wetwood (causative agent: phytopathogenic bacterium *Leliottia (Erwinia) nimipressuralis* Carter, 1945) and tuberculosis (causative agent: phytopathogenic bacterium *Pseudomonas syringae* pv.savastanoi (Smith 1908) Young et. Al. 1978)) [5, 6].

Decaying trees are colonized by tinder fungus, whose spores penetrate through wounds on the trunks. One of the most harmful diseases of birch is wetwwod, which is caused by the bacterium *Leliottia nimipressuralis* [24]. Usually, the earliest signs of the development of bacteriosis are thinning of the crowns, the appearance of dry tops, and premature yellowing and falling of leaves. If such signs are detected, attention should be paid to the presence of brown streaks of exudate on the branches and trunks. Trees weakened by bacterial wetwood are actively colonized by trunk pests [24].

1.4. Stability of plantations in urban ecosystems

In addition to abiotic and biotic factors common in natural ecosystems, the growth and development of plants in the city are influenced by specific physical and chemical factors [2, 3, 12, 21]. Physical factors of influence are manifested in soil and climatic conditions, the content of basic nutrients, soil density, acidity of the water regime, etc. Chemical factors are associated with smoke, gas, and dust, changes in lighting and temperature regimes, and anthropogenic factors are associated with violations of agricultural techniques for planting and caring for stands, mechanical damage, and recreational pressure. Plants weakened by these factors become susceptible to damage by phytophagous insects and pathogens [16].

The growth rate and health of trees depend on both hereditary traits (genotype) and environmental conditions that determine the phenotype. Identifying trees that are characterized by the fastest growth or the greatest resistance to adverse effects of certain environmental factors, with subsequent reproduction, is one of the tasks of selection [44].

The resistance of trees to insect damage or disease is related to two mechanisms. One of them (resistance) allows a tree to avoid damage or damage due to morphological features (has thorns, waxy coating), physiological features (repels with an unpleasant odor, fills with resin), or a certain shift in the life cycle. For example, the leaves of a late-forming oak tree bloom later than the caterpillars of the green oak leaf beetle hatch from their eggs, and these insects do not damage such trees. The second mechanism (tolerance) reflects the ability of a tree to restore its growth or reproduction rate after damage. These mechanisms are genetically inherited, so the selection of resistant families or clones is one way to reduce losses from the action of harmful organisms [35, 37].

Studies in many regions show that mixed-species, mixed-age, and multi-tiered stands are more resistant to the adverse effects of insects, mammals, pathogens, wind, or fire damage compared to pure, same-aged, and single-tiered stands. Such stands also recover more quickly after damage or injury [17].

Signs that are a manifestation of resistance are sufficient growth intensity, crown density, and leaf or needle color. Indirect evidence of resistance is the proportion of damaged, populated, and withered trees, the degree of disturbance of the structure and density of the soil, and the development of undergrowth and grass cover. Resistance refers to the resistance of organisms to the action of other organisms, substances, or other factors. Thus, plants can be resistant to drought, frost, damage by certain pathogens, damage by insects or mites, and treatment with herbicides, and insects, in turn, to damage by entomopathogenic microorganisms and treatment with insecticides, phytopathogenic fungi to the action of competitive organisms and treatment with fungicides [44].

Any city has recreational areas, which include city and suburban parks, forest parks, meadow parks, hydroparks, landscape and architectural museums, and suburban forests of the city's green zone. In each type of plantation, the composition of trees and shrubs should be selected taking into account the mechanical and chemical composition of the soil, the range of tolerance to the level of moisture, resistance to industrial and domestic pollution, the ability to absorb pollutants from the atmosphere or soil, the ability to ionize atmospheric air. The presence of branched crowns with dense foliage or dense needles to absorb noise, as well as the decorativeness of crowns, flowers, and fruits, is also important [47].

The resistance of trees to insect damage or disease is associated with two mechanisms. Thanks to resistance, a tree avoids damage due to its morphology, physiology, or phenology. Thanks to tolerance, a tree restores its condition, growth rate, or reproduction intensity after damage. The growth intensity and condition of trees depend on hereditary traits and environmental conditions. One of the tasks is to identify tree species and varieties that are characterized by the fastest growth or the greatest resistance in urban communities to the most harmful environmental factors. Mixed species, mixed-age, and multi-tiered stands are most resistant to the adverse effects of many abiotic, biotic, and anthropogenic factors compared to pure, same-age, and single-tiered stands. In forest parks, parks, and street stands, the composition of trees and shrubs should be selected taking into account the mechanical and chemical composition of the soil, the range of tolerance to moisture levels, resistance to industrial and domestic pollution, the ability to absorb pollutants from the atmosphere or soil, etc.

1.5. Tree species of green stands in Zhytomyr and insect miners on them

We examined the stands in the Shoduarivskyi Park, and the 30-richchia Peremohy, the streets of the Center – Peremohy St., Kyivska and Velika Berdychivska St., as well as the streets of the industrial zone – Koroliova and Paradzhanova, where the stands grow near roads with intensive traffic and railway tracks. In the surveyed stands, the most common tree species are common oak (*Quercus robur* L.), linden (*Tilia cordata* Mill.), maple (*Acer platanoides* L.), white poplar (*Populus alba* L.), common chestnut (*Aesculus hippocastanum* L.), black poplar (*Populus nigra* L.), elms (*Ulmus laevis* Pall., Ulmus *glabra* Huds.), robinia (*Robinia pseudoacacia* L.). During the survey of the stands, we found insect miners from the order of Lepidoptera of the Gracillariidae family: – on common oak – *Acrocercops brongniardella* (Fabricius, 1798) (Fig. 1); – on common chestnut – *Cameraria ohridella Deschka* & Dimic, 1986 (Fig. 1); – on robinia – *Parectopa robiniella* (Clemens, 1863) and *Macrosaccus robiniella* (Clemens, 1859) (Fig. 2); – on linden – *Phyllonorycter issikii* (Kumata, 1963) (Fig. 3);– on black poplar – *Phyllonorycter populifoliella* (Treitschke, 1833) (Fig. 3).

We paid attention to studying the distribution features of these species. In the 2020 growing season, the chestnut miner was the most common, while the linden miner and white acacia miner were found to a much lesser extent.

Fig. 1. *Mine of the Acrocercops brongniardella on an oak leaf (left) and mines of the Cameraria ohridella on a chestnut leaf (right)*

Fig. 2. *Mines of the Parectopa robiniella (left) and mines of the Macrosaccus robiniella (right)*

Fig. 3. *Mines of the Phyllonorycter issikii (left) and mines of the Phyllonorycter populifoliella (right)*

1.6. Seasonal dynamics of the distribution of the chestnut miner

The chestnut miner was first discovered in 1984 in Macedonia near Lake Ohrid [44]. Soon it quickly spread to almost all countries of Western, Central and Eastern Europe. It is a narrow oligophagous, as it can inhabit various species of the genus Aesculus [41].

Butterflies overwinter in leaf litter. Therefore, one of the means of preventing the spread of the chestnut miner in the city is to clean up and compost fallen leaves. Butterflies fly out of their wintering grounds in late April-early May, initially they are on the bark of trunks, and after sufficient development of the leaves, they begin to lay eggs in them. This phenomenon coincides with the mass flowering of bitter chestnut. During the summer, leaf damage increases, and in August the leaves of some trees are completely covered with mines and fall prematurely. Young trees planted in the spring were not colonized by the first generation of the pest, but in August, chestnut borer mines were found on the leaves of these trees. The caterpillars went through six stages of development, and the mines of caterpillars of different ages differed in shape and size (Fig. 4).

Fig. 4. *Chestnut leaf miner caterpillar of the 4th age*

The first pupae of the chestnut miner were found in mid-June, the first exuviae in the third decade of June. By this time, the leaves were populated by the miner at the entire height of the crowns, the leaves began to turn yellow and curl, and butterflies of a new generation appeared on the trunks. Later, it was possible to simultaneously detect individuals of different stages and generations. In the seasonal dynamics of the density of chestnut miner mines, three waves were recorded with maxima in the second decade of June (12.8 mines/leaf), the second decade of July (56.4 mines/leaf) and the third decade of August (28.6 mines/leaf) (Fig. 5).

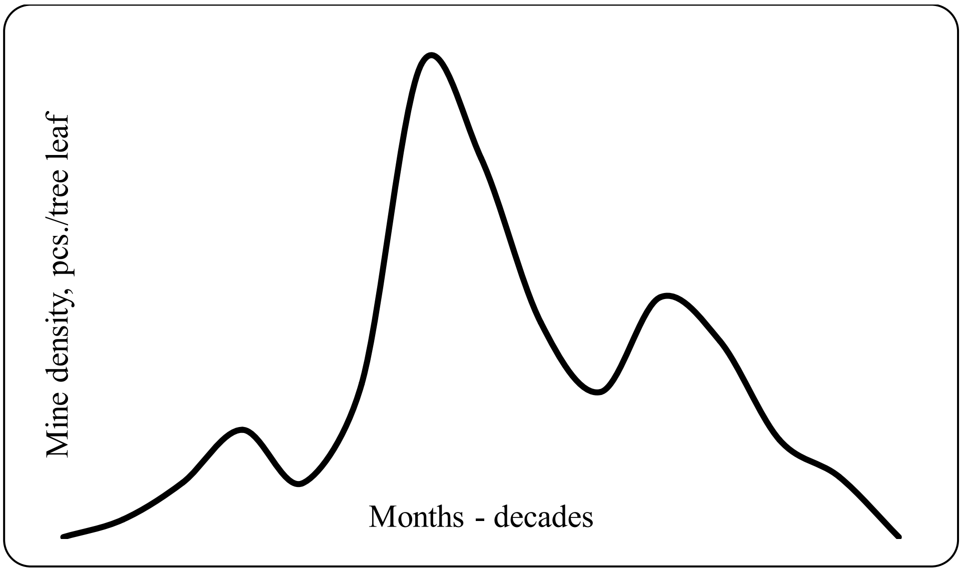

Fig. 5. *Seasonal dynamics of the average density of chestnut miner mines (pcs/leaf; averaged over all recording areas)*

The population of chestnut by the chestnut miner increased slowly at first, sharply in July, and slowly again at the end of August (Fig. 6).

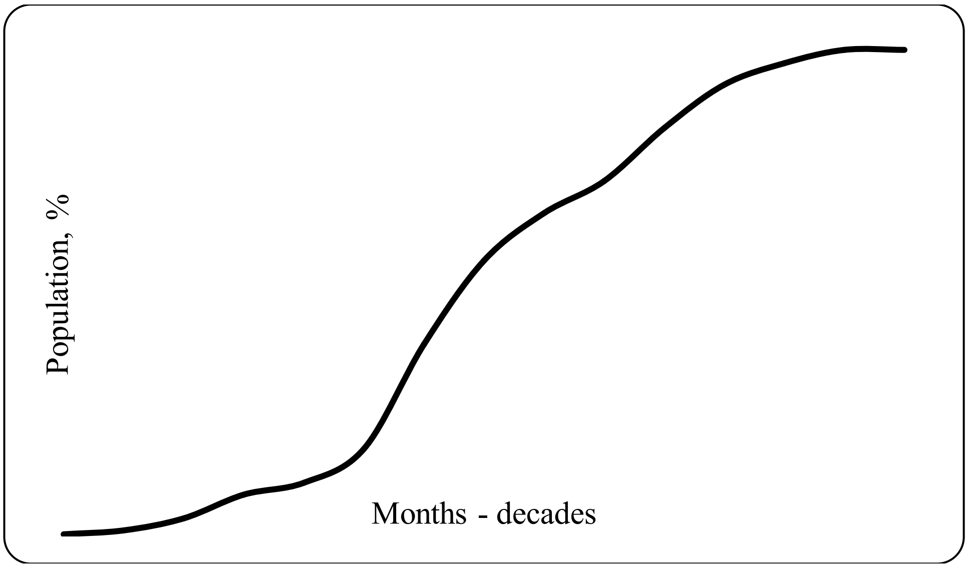

Fig. 6. *Seasonal dynamics of the population of common chestnut by the chestnut mine*

A slow increase in population occurred during the development of the 1st generation, a rapid one during the development of the 2nd generation. From the 3rd decade of May to the end of the flight of the 3rd generation (2nd – 3rd decade of August) with separate periods of a sharp increase in the indicator, which correspond to the flight dates of butterflies of the corresponding generations (Fig. 5).

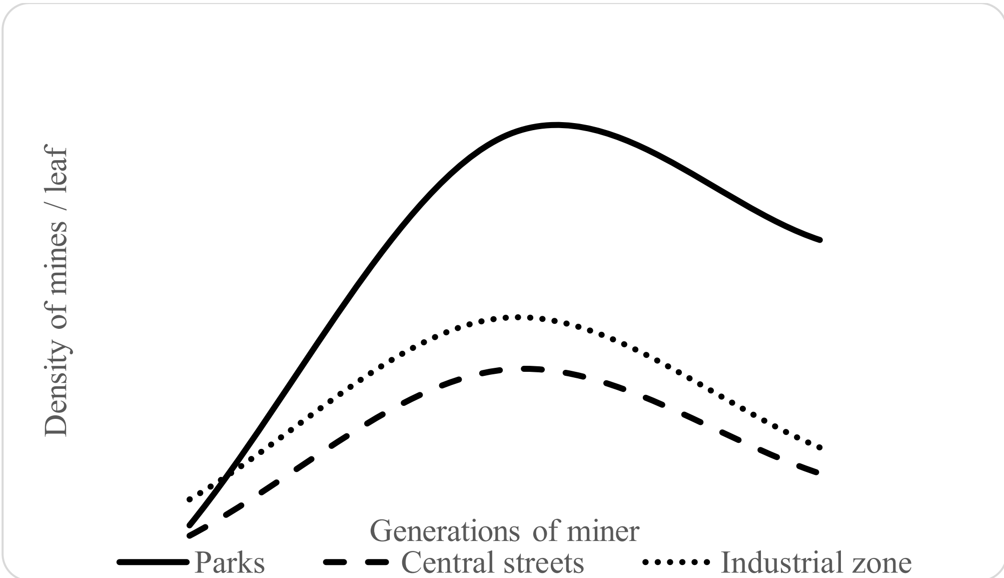

Fig. 7. *Dynamics of the average density of chestnut miner mines at different recording points (pcs./leaf)*

At the same time, if there was a place on the leaf, the butterflies laid eggs on the leaves where the mines of the previous generation were already located, and the overall population changed slightly.

The average density of mines per leaf was calculated for each of the three generations of the chestnut leaf miner for three groups of recording points: parks, central streets, and streets of the industrial zone (Fig. 7, Table 2).

Table 2. *Dynamics of the density of chestnut miner mines in different groups of stands*

Months, decade	**Mine density, pcs./tree leaf**			
	Parks	**Downtown streets**	**Streets of the industrial zone**	**Average**
V-2	0	0	0	0
V-3	0,5	2,1	3,6	2,1
VI-1	1,8	8,2	9,4	6,5
VI-2	8,8	11,9	17,8	**12,8**
VI-3	3,2	6,2	9,8	6,4
VII-1	26,2	15,8	12,8	18,3
VII-2	78,2	42,8	48,2	**56,4**
VII-3	58,2	33,8	43,5	45,2
VIII-1	38,2	16,4	22,1	25,6
VIII-2	22,1	12,3	17,4	17,3
VIII-3	52,4	15,7	17,8	**28,6**
IX-1	42,3	13,8	14,2	23,4
IX-2	18,1	8,3	8,5	11,6
IX-3	12,1	5,1	4,5	7,2
X-1	0	0	0	0

Analysis of the data obtained shows that at the beginning of the season, the density of chestnut miner settlements differed little at different recording points, although in the parks and streets of the center, where fallen leaves were removed in the fall, this indicator was slightly lower than on the streets of the industrial zone.

In subsequent generations, the density of chestnut miner settlements increased most intensively in parks and reached a maximum of 78.2 mines/leaf. On the streets of the city center, the maximum density of chestnut miner settlements was 42.8 mines/leaf, and in the industrial zone – 48.2 mines/leaf. The lower density of mines in street plantings may be due to the fact that the leaves of the common bitter chestnut were also affected by burns due to the effects of industrial and motor vehicle emissions. At the end of summer, a significant part of the leaves fell off, and the rest were not suitable for settlement by the chestnut miner, since they already contained many mines of this pest from previous generations, as well as traces of burns and fungal damage. Therefore, in all areas, the density of mines at the end of the development of the third generation is lower than that of the second generation.

During the survey of street and park plantings, a dependence of the damaged area of leaves of common chestnut on the density of mines was established (Fig. 8). At the same time, at high population density, such a relationship was absent due to competition between pest individuals.

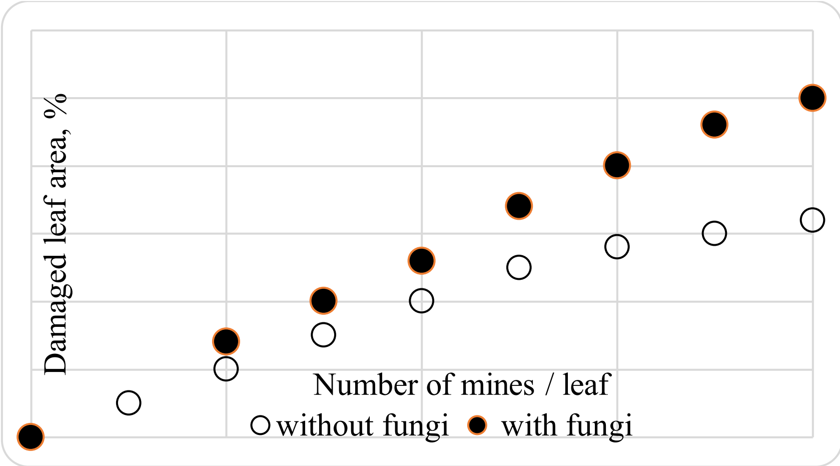

Fig. 8. *Dependence of the damaged area of a leaf of common chestnut on the density of chestnut miner mines in the absence and presence of additional fungal damage*

The use of the revealed dependence for predicting the level of leaf damage is not promising, since chestnut leaves are also damaged by vehicle emissions and affected by pathogens. These factors together lead to a decrease in the assimilation surface and a general weakening of trees. Thus, with 30 mines on a leaf, the damaged area was 15.2 and 20.1% in the presence and absence of fungal damage, respectively (Fig. 3.8).

1.7. Seasonal dynamics of the distribution of the *Phyllonorycter issikii*

Ph. issikii is widespread in Japan [45]. The caterpillars form folded mines on the underside of linden leaves. It entered in Kyiv in 1987, and now it is widespread in Ukraine. It is a narrow oligophagous, as it can inhabit various species of the genus *Tilia* Mill. The number of *Ph. issikii* in the city is not high compared to the forest [29].

We found the *Ph. issikii* only in park plantings. Butterflies flew out of wintering grounds in early May, and mines could be seen in late May, when the linden leaves reached full size. Single mines appeared in the first decade of June. Mines are located mainly on the underside of the leaf, often between the central and other large vessels (Fig. 9).

The caterpillar of the *Ph. issikii* passed through 4 instars (Fig. 10) and pupated in the mine, usually at the end of June. After 7–9 days, the pupa broke through the mine and emerged for most of its length.

Fig. 9. *Miner on the underside of a linden leaf*

Fig. 10. *Ph. issikii caterpillar in a mine*

The first butterflies of the new generation flew out in early July. They mated and laid eggs on the leaves. Caterpillars of the second generation developed in August. Pupae were found in late August, and adults in September. Butterflies overwintered in deep cracks in the bark, cracks in fences and buildings.

In 2020, the linden miner had a low population density - the maximum value of the indicator was noted in the second decade of August and was 0.4 mines/leaf (Fig. 11).

In the seasonal dynamics of the mine density, two maxima can be clearly distinguished, which correspond to the periods of the end of hatching of larvae of the I and II generations. The first maximum (0.1 mines/leaf) was noted in the second decade of June, and the second (0.4 mines/leaf) - in the second decade of August.

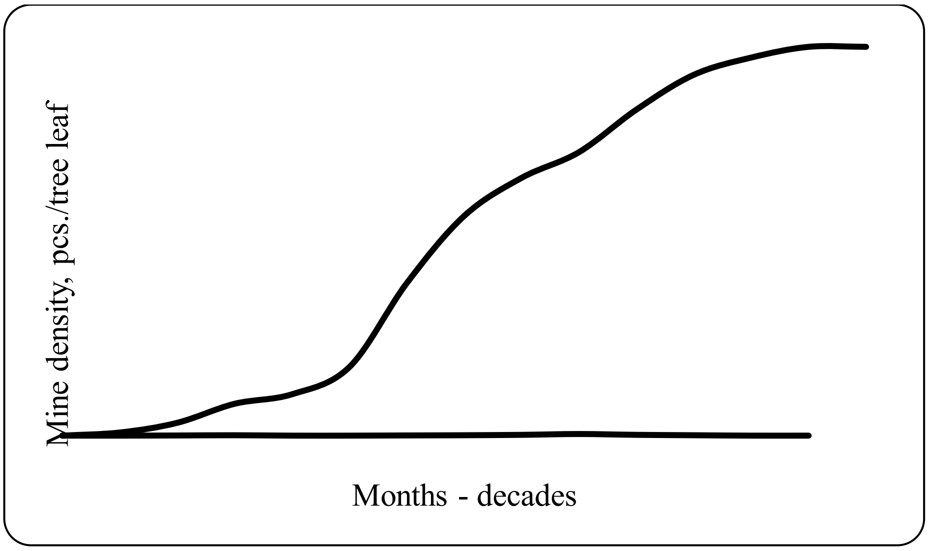

Fig. 11. *Seasonal dynamics of the average density of Ph. issikii mines (pcs/leaf; averaged over all recording areas)*

The population of linden leaves by the *Ph. issikii* at the beginning of June was 1.1% (Fig. 12).

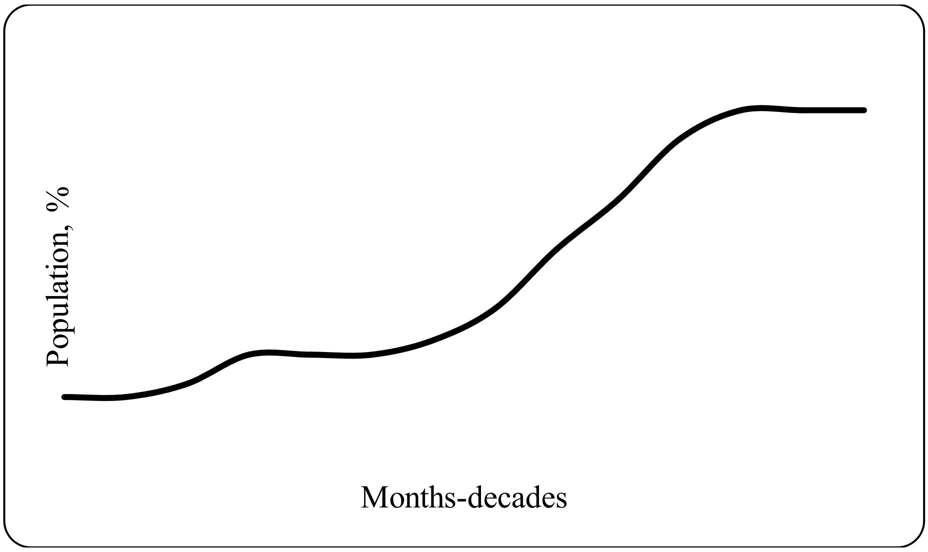

Fig. 12. *Seasonal dynamics of the population of linden Ph. issikii*

As the summer generation of butterflies fledged, leaf occupancy increased from 4.7% in the second decade of July to 23.7% in early September.

1.8. Seasonal dynamics of the distribution of *M. Robiniella*

M. robiniella was introduced to Switzerland from North America in 1983 [46]. By 2000, the species had spread across Europe. The white acacia motley moth entered Italy from North America in 1970 and is now widespread in many European countries, including Ukraine [1].

In 2020, we found *M. robiniella* only in parks. The density of mines was low, but three maxima can be distinguished in its dynamics (Fig. 13).

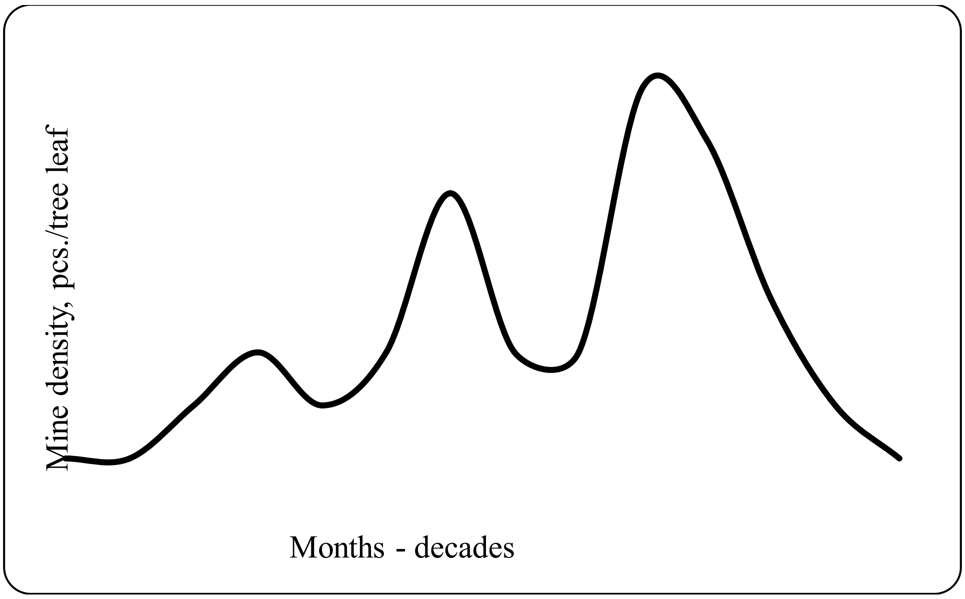

Fig. 13. *Seasonal dynamics of the average density of M. robiniella mines (items/leaf; averaged over all research areas)*

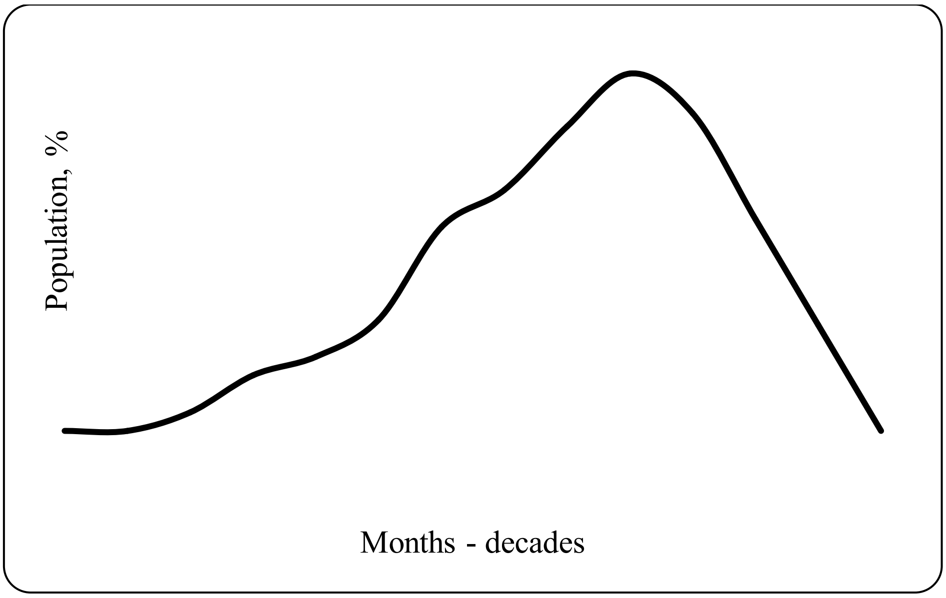

Fig. 14. Seasonal dynamics of the population M. robiniella

The first maximum of the mine density was 0.02 pcs./leaf (second decade of June), the second – 0.05 pcs./leaf (second decade of July) and the third – 0.07 pcs./leaf (second decade of August).

The population of Robinia by the miner during the first wave (second decade of June) was 0.4%, during the second wave (second decade of July) – 1.5%, respectively, and during the last wave (second decade of August) – 2.7%, respectively (Fig. 14).

P. robiniella was found singly. *M. robiniella* and *P. robiniella* feed only on plants of the genus Robinia. The last-instar caterpillars pupate in mines in white oval cocoons. Both species develop in 2–3 generations per year, which usually overlap.

Thus, in 2020, among the six species of insect miners identified, only the chestnut miner became widespread. The remaining species had low numbers and did not cause noticeable damage to trees. We suggest monitoring the distribution and development of the identified insect miners. Removing fallen leaves in autumn allows you to reduce the number of the chestnut miner of the spring generation and does not affect the further growth of its number. Therefore, it is necessary to provide for a gradual replacement of the common bitter chestnut with other species.

Conclusions and Production Recommendations

1. Urban stands play a significant role in creating a favorable environment for people, mitigating the climate, absorbing dust and emissions, but they themselves are weakened by anthropogenic factors and vulnerable to pests and pathogens, in particular to alien species.

2. In urban conditions, the spread of insects with a smaller size, secretive lifestyle and with a sucking mouthpart increases, the participation of eruptive species decreases, and alien species are added.

3. Among the diseases, trunk rots are the most dangerous. The crowns of affected trees often have a good crown appearance, but during strong winds, branches or tops can injure people or damage vehicles.

4. The resistance of trees to damage by insects or pathogens is associated with two mechanisms. Thanks to resistance, a tree avoids damage or damage due to its morphology, physiology or phenology. Thanks to tolerance, a tree restores its condition, growth rate, or reproductive intensity after damage has been caused.

5. The growth intensity and condition of trees depend on hereditary traits and environmental conditions. One of the tasks is to identify the species and varieties of trees that are characterized by the fastest growth or the greatest resistance in urban ecosystems to the most harmful environmental factors.

6. In the surveyed stands, the most common tree species are common oak (*Quercus robur* L.), linden (*Tilia cordata* Mill.), maple (*Acer platanoides* L.), white poplar (*Populus alba* L.), common chestnut (*Aesculus hippocastanum* L.), black poplar (*Populus nigra* L.), elms (*Ulmus laevis* Pall., *Ulmus glabra* Huds.), robinia *(Robinia pseudoacacia* L.). During the survey of the stands, we found insect miners from the order of Lepidoptera of the Gracillariidae family: on common oak – *Acrocercops brongniardella* (Fabricius, 1798); on common chestnut – *Cameraria ohridella* Deschka & Dimic, 1986; on robinia – *Parectopa robiniella* (Clemens, 1863) and *Macrosaccus robiniella* (Clemens, 1859); on linden – *Phyllonorycter issikii* (Kumata, 1963); on black poplar – *Phyllonorycter populifoliella* (Treitschke, 1833).

7. In the dynamics of the density of chestnut leaf miner mines, three maxima were recorded: in the second decade of June (12.8 mines/leaf), the second decade of July (56.4 mines/leaf) and the third decade of August (28.6 mines/leaf). The population increased slowly during the development of the first generation, quickly during the development of the second generation and slowly during the development of the third generation. The latter is associated with the lack of space on the leaves for settlement.

8. In spring, the density of chestnut leaf miners was the lowest in parks and streets of the center, where fallen leaves were removed. At the same time, in subsequent generations, the maximum value of the indicator was 78.2; 42.8 and 48.2 mines / leaf in parks, streets of the center and industrial zone.

9. The damaged area of bitter chestnut leaves depends on the density of chestnut leaf miners, damage by fungi and technogenic factors.

10. In the seasonal dynamics of the density of lime leaf miners, two maxima coincide with the periods of the end of the appearance of larvae of the 1st and 2nd generations. The first maximum (0.1 mines / leaf) was noted in the 2nd decade of June, and the second (0.4 mines / leaf) - in the 2nd decade of August. The population of lime leaves by lime leaf miners in early June was 1.1%, in early September - 23.7%.

11. In the dynamics of the density of white acacia miner mines, the first maximum was 0.02 pcs./leaf (second decade of June), the second – 0.05 pcs./leaf (second decade of July) and the third – 0.07 pcs./leaf (second decade of August). The population of leaves during this time increased from 0.4 to 2.7%

12. In forest parks, parks and street plantings, the composition of trees and shrubs should be selected taking into account the composition of the soil, tolerance to the level of moisture, resistance to industrial and domestic pollution, the ability to absorb pollutants from the atmosphere or soil, etc.

13. It is necessary to monitor the condition of trees in urban stands, assess the impact of factors of various nature and clarify the conditions that can be influenced by economic activities in the urban environment. This will allow to increase the ecological role of plantings in the urban environment.

REFERENCES

1. Andreieva O. Yu., Goychuk A. F., Kulbanska I. M., Shvets M. V., Vyshnevsky A. V. Adventitious insect miners in green spaces of Zhytomyr. *Forestry and agroforestry.* 2022. Issue 140. P. 57–63.
2. Babiy V. F., Khudova V. M., Kondratenko O. Ye., Ponomarenko A. M. The influence of transport factors on the ecological state of large cities. *Hygiene of populated areas: collection of scientific works*. 2011. Issue 58. P. 57–60.
3. Vergeles Yu. I., Galetich I. K., Danova K. V., Zadorozhny K. M., Reshetchenko A. I., Rybalka I. O. Reactions of *Acer platanoides* L. in urban plantations to the influence of a complex of physical factors of anthropogenic origin. Man and Environment. *Problems of Neoecology*. 2016. Issue 3–4 (26). P. 111–125.
4. Hlibovytska N. I., Parpan V. I. Heart-leaved linden *(Tilia cordata* L.) as a bioindicator of the state of pollution of urbanized areas with heavy metals. *Ecology and noospherology.* 2013. No. 3–4. P. 89–94.
5. Goychuk A. F., Drozda V. F., Kulbanska I. M. Tuberculosis of common ash in Western Podillia of Ukraine: etiology, symptoms, pathogenesis. *Scientific Works of the Forestry Academy of Sciences of Ukraine.* 2018. Issue 16. P. 31-40.
6. Goychuk A. F., Drozda V. F., Shvets M. V. Bacterial dropsy of downy birch in plantations of Zhytomyr Polissya, Ukraine (scientific and methodological recommendations for enterprises of the State Agency of Forest Resources of Ukraine). Kyiv: NULES, 2017. 26 p.

7. Zhupinska K. Yu. Stem pests on plants of the genus Populus L. Bulletin of the Kharkiv National Agrarian University. Series "Phytopathology and Entomology". 2019. No. 1–2. P. 46–55.
8. Zaitseva I. A. Dendrobiont phyllophages of *Tilia* L. in the Dnipro stands: spring phenological group. *Issues of bioindication and ecology*. 2018. Issue 23 (1). P. 146–168.
9. Zinchenko O. V., Kukina O. M. Some biological features of the ash black sawfly *Tomostethus nigritus* Fabricius, 1804 (Hymenoptera: Tenthredinidae). *News of the Kharkiv Entomological Society.* 2015. Volume XXIII, Issue 2. P. 70–74.
10. Kardash E. S. Features of the trophic activity of phyllophages in green areas of Kharkiv (Ukraine). *News of the Kharkiv Entomological Society*. 2021. Vol. XXIX, issue 1. pp. 77–84. DOI: 10.36016/KhESG-2021-29-1-7.
11. Kardash E. S., Sokolova I. M. Structure of phyllophage insect complexes of deciduous areas of Kharkiv. *Biodiversity, ecology and experimental biology*. 2020. Issue 22(1). pp. 68–81.
12. Karpyn N. I. Phytopathogens and pests of species of the genus *Tilia* L. in the conditions of the city of Lviv. *Scientific Bulletin of the National Technical University of Ukraine.* 2016. Issue 26.4. pp. 76–82.
13. Kolenkina M. S. The condition of small-leaved linden (*Tilia cordata* Mill.) in green spaces of the city of Kharkiv (according to spring survey data). *Scientific Bulletin of the National Technical University of Ukraine.* 2020. Issue 30(5). Pp. 25–30.
14. Kukina O. M., Kardash E. S., Shvidenko I. M. Assessment of the harmfulness of gnawing insects-phyllophagous in urban stands of Kharkiv. *Current problems, ways and prospects for the development of landscape architecture, gardening, urban ecology and phytomelioration*: materials of the international scientific-practical conference (Bila Tserkva, September 16–17, 2021). Bila Tserkva: BNAU, 2021. P.76–78.
15. Kucheryavyi V. P. Urban ecology. Lviv: Svit, 2001. 440 p.
16. Lavrov V. V., Slobodenyuk O. I., Savchuk L. A. State of green spaces of the city of Uman. *Scientific Bulletin of the National Technical University of Ukraine*. 2019. Vol. 29, No. 8. P. 25–30.
17. Levon F. M. Green plantations in an anthropogenically transformed environment: monograph. Kyiv, 2008. 364 p.
18. Матковська С. І. Оцінювання видового складу захисних насаджень промислового мікрорайону міста Житомира. Наук. вісник НЛТУ України. 2015, 25.2. С.115–119.
19. Мацях І. П., Крамарець В. О. Інвазії комах-філофагів на територію України. Наукові праці Лісівничої академії наук України. 2020. 20. С. 11-25.
20. Masalsky V. P., Kuznetsov S. I. The influence of park plantations on the temperature regime of the urban environment. Scientific Bulletin of the National Technical University of Ukraine. 2018. Issue 28 (7). P. 49–52.
21. Masalskyi V. P., Mordatenko I. L. Gas and smoke resistance of cultivated species of the genus Tilia L. in the urbanized environment of the Right-Bank Forest-Steppe of Ukraine (on the example of street plantings in the cities of Kyiv and Bila Tserkva). Scientific Bulletin of the National Technical University of Ukraine. 2014. Issue 24.4. P. 104–108.
22. Matusyak M. V. Current state of development of diseases and pests of green plantings in Vinnytsia and assessment of their impact on the viability of woody plants. Agriculture and forestry: collection of scientific works of the Ukrainian Academy of Sciences. 2019. Issue 13. P. 217–227.
23. Meshkova V. L. Monitoring of biotic factors of tree weakening in urban coenoses. Kolesnikov readings. *Dedicated to the memory of O.I. Kolesnikov*: materials of the All-Ukrainian scientific and practical conference (scientific electronic publication), Kharkiv, November 25, 2020. Kharkiv. KhNUMG, 2020. Pp. 46–48.
24. Meshkova V. L., Skrylnyk Yu. Ye., Koshelyaeva Ya. V. Sanitary condition of birch in the Left Bank forest-steppe of Ukraine: monograph. Kharkiv: Machulin, 2023. 163 p.
25. Pankiv N. Ye., Teterko N. Z. Assessment of atmospheric air pollution due to traffic congestion on the streets of Lviv. *Scientific Bulletin of the National University of Technology of Ukraine*, 2016. Issue 26(8). P. 215-223.
26. Poltoratska V. M., Tymoshenko O. A., Boyko A. O., Shalamova A. D. Assessment of the species diversity of biocenoses of the city of Dnipro. *Bulletin of the Dnieper State Academy of Civil Engineering and Architecture*. 2019. No. 6. P. 259–260.
27. Puzrina N. V., Meshkova V. L., Myronyuk V. V., Bondar A. O., Tokareva O. V., Boyko G. O. Monitoring of harmful organisms of forest ecosystems: a textbook. Kyiv: NULES of Ukraine, 2021. 274 p.
28. Puchkov A. V. Beetles (Coleoptera, Carabidae) of transformed cenozes of Ukraine. Kyiv; 2018. 448 p.
29. Skrylnyk Yu. Ye., Zinchenko O. V. Harmful insects and fungal diseases of maples (Acer L.) in green spaces of Kharkiv. *Fundamental and applied problems of modern ecology and plant protection:* materials of the scientific and practical conference dedicated to the 85th anniversary of the Faculty of Plant Protection (1932–2017) of the Dokuchaev KhNAU, September 14–15, 2017, Kharkiv: abstracts. Kharkiv, 2017. P. 90–93.
30. Skrylnyk Yu. Ye., Koshelyayeva Ya. V., Zhupinska K. Yu., Meshkova V. L. Some features of xylophagous insects that determine their harmfulness to plants of the genus Populus. *Entomological readings in memory of outstanding scientists-entomologists V. P. Vasyliev and M. P. Dyadech*. Materials of the All-Ukrainian scientific and practical online conference dedicated to the 110th anniversary of the birth of outstanding scientists-entomologists of the NAS of Ukraine Vadim Petrovich Vasyliev and Professor Mykola Platonovich Dyadech (March 21, 2023). Kyiv, 2023. P.81–85.

31. Sobchenko V. F. Situational resistance of maples to low wintering temperatures in the conditions of the National Arboretum "Sofiivka" NAS of Ukraine. *Scientific Bulletin of the National University of Lithuania and Lithuania of Ukraine: collection of scientific and technical works*. Lviv: RVV of the National University of Lithuania and Lithuania of Ukraine. 2007. Issue 17.8. P. 38–45.
32. Sokolova I. M., Shvidenko I. M., Kardash E. S. Prevalence of gnawing phyllophage insects in plantations of Kharkiv. *Ukrainian Entomological Journal*. 2020. Issue 1–2 (18). P. 67–79.
33. Shevchenko S. M., Mironova N. G., Efremova O. O., Kratyuk O. L. Species diversity and features of the distribution of wood-destroying fungi in the Mykhailo Chekman Park of Culture and Recreation of the City of Khmelnytskyi. *Scientific Bulletin of the National Technical University of Ukraine*. 2019. Issue 29 (1). P. 24-29.
34. Branco M., Nunes P., Roques A., Fernandes M. R., Orazio C., Jactel H. Urban trees facilitate the establishment of non-native forest insects. *NeoBiota.* 2019, Vol. 52. P. 25–46.
35. Callow D., May P., Johnstone D. M. Tree vitality assessment in urban landscapes. *Forests.* 2018. Vol. 9(5). 279.
36. Davydenko K., Borysova V., Shcherbak O., Kryshtop Ye., Meshkova V. Situation and perspectives of ash (Fraxinus spp.) in Ukraine: focus on eastern border. *Baltic Forestry*. 2019. Iss. 25 (1). Pp. 193–202.
37. Goychuk, A., Kulbanska, I.,Vyshnevskyi, A., Shvets, M., & Andreieva, O. (2022). Spread and harmfulness of infectious diseases of the main forest-forming species in Zhytomyr polissia of Ukraine. *Scientific Horizons*, 25(9), 64-74.
38. Kukina O., Kardash E., Shvydenko I. Expected harmfulness of gnawing phyllophagous insects in urban stands of Kharkiv-city. *Folia Forestalia Polonica*, Series A – Forestry, 2021. Vol. 61 (4), 267–275.
39. Meshkova V. Alien phytophagous insects in forest and urban stands of Ukraine. *Bucovina Forestieră*. 2022. Vol. 22(1). P. 29–40.
40. Meshkova V. Assessment and prediction of biotic risks in the forests of Ukraine. *Bucovina Forestieră*. 2021. Vol. 21(1). P. 83–92.
41. Meshkova V. Foliage-browsing Lepidoptera (Insecta) in deciduous forests of Ukraine for the last 70 years. *Proceedings of the Forestry Academy of Sciences of Ukraine.* 2021. Vol. 22. P. 173-179.
42. Meshkova V., Kukina O., Zinchenko O., Davydenko K. Three-year dynamics of common ash defoliation and crown condition in the focus of black sawfly *Tomostethus nigritus* F. (Hymenoptera: Tenthredinidae). *Baltic Forestry*. 2017. Vol. 23(1). P. 303–308.
43. Meshkova V. L., Mikulina I. M. Seasonal development of horse-chestnut leafminer, *Cameraria ohridella* Deschka et Dimić, 1986 (Lepidoptera: Gracillariidae) in the green stands of Kharkov. The Kharkov Entomol. Soc. Gaz. 2013. XXI (2). P. 29–37.
44. Sefrova H., Lastuvka Z. Dispersial of the horse-chestnut leafminer *Cameraria ohridella* in Europe: its course, ways and causes. Entomol. Zeit. Stuttgart, 2001. 111. S. 195–198.
45. Sefrova H. *Phyllonorycter issikii* (Kumata, 1963) – bionomics, ecological impact and spread in Europe (Lepidoptera, Gracillariidae). Acta univ. agric. et silvic. Mendel. Brun. 2002. L, No 2. P. 99–104.
46. Sefrova H. *Phyllonorycter robiniella* (Clemens, 1859) – egg, larvae, bionomics and its spread in Europe (Lepidoptera, Gracillariidae). Acta univ. agric. et silvic. Mendel. Brun. 2002. L., No 3. P. 7–12.
47. Tokarieva O., Meshkova V., Puzrina N. Pest management in forests of Eastern Europe (Manual). NULES of Ukraine, 2022. 285 p.

COMPOSITION SOLUTIONS FOR THE CREATING FLOWER ARRANGEMENTS IN THE KROPYVNYTSKY CITY

Tetiana Boiko
Associate Professor, Kherson State Agrarian and Economic University
ORCID ID: 0000-0003-3864-2036

Pavlo Boiko
Associate Professor, Kherson State Agrarian and Economic University
ORCID ID: 0000-0003-0658-0846

Introduction.

Green spaces of modern cities are an integral part of modern urban development. Traditional elements of landscape design are parks, boulevards, squares, green areas of streets and residential areas [1]. Flower beds are important elements of large green spaces. They affect the appearance of streets, squares and parks, diversify the urban landscape, contribute to the creation of ecological balance and affect the emotional state of the population. Floral design gives landscape objects unique properties, allows you to diversify space, add bright colors and logically complete compositions.

The spatial arrangement of flower gardens in modern urban planning should be subordinated to the general concept of city development and harmoniously fit into existing objects of the area in accordance with the stylistic decision. Their creation and support is an investment in the sustainable development of a modern city, its tourist and recreational attractiveness and, in general, in thфe creation of an ecological balance of urban ecosystems.

The goal of our work was to establish the features of creating flower arrangements in the city of Kropyvnytskyi.

Research materials and methods. The study of flower arrangements in the city of Kropyvnytskyi was conducted during 2022-2024. Research was conducted in the Chornobyl Square, Fortechny Voly, the square in front of the city council, Teatralna Square, Shevchenko Square, Bohdan Khmelnytskyi Square, Soborna Square, Kavaleriyska Street, Chykalenko Street, Shevchenko Square, Kovalevsky Park, Fontannyy Square, Popova Street, Patsayeva Street, the triangle along Chykalenko Street, the boulevard between Patsayeva and Volkova Streets, the Dendropark, as well as flower beds in the inter-quarter landscaping of the Fortechny District.

Types of flower gardens were established according to the recommendations of L.P. Ishchuk et al. [2,3], V.P. Kucheryavy and V.V. Kucheryavy [1]. The species composition was established according to the «Determinant of higher plants of Ukraine» [4], and was specified according to scientific publications and reference literature [5-11].

A flower garden is a delimited area where ornamental plants are grown, a general term for any group of ornamental plants. They create a unique charm of the play of shapes of flowers and leaves, their size and color. The design for each flower garden is created separately, so that the appearance of the territory or a separate zone becomes more expressive. There are no uniform requirements for the form, execution of such compositions. It is important that they are combined with the chosen style of landscape design [2].

These can be flowering and decorative herbaceous shrubs, grasses and cereals, small trees (deciduous and coniferous). In other words, any low plants have decorative value. The main task of flower growers in landscape design is decoration. Various areas, such as gardens, parks, areas in front of the entrance to houses, etc. The lawn can be used as a background for plants in the flower garden.

Plants for flower beds are selected so that they harmoniously combine appearance (color, shape, size) and vegetative characteristics (growth and development, time and duration of flowering, shade tolerance, resistance to soil conditions and moisture requirements).

Depending on the type of plants collected in the flower garden, the nature of the site and its geometry, flower gardens are divided into different types. This division is quite conditional and may vary slightly depending on the configuration of the site and the designer's idea.

Today, there is a wide variety of decorative compositions and types of garden ensembles, sometimes even for experienced gardeners it is difficult to avoid confusion in terms and their meanings. The boundaries between flowerbeds, rabatkas, mixborders and groups are becoming less obvious. However, despite this, the basic principles and simple elements remain the basis for creating spectacular effects in the garden. This also applies to the main types of flower beds, which are one of the key components of garden design.

In the modern variety of methods for creating decorative garden compositions, a large selection of plants and new styles, variations in the design of flower beds seem to have endless possibilities. Here, the importance of creating compositions is limited only by objective conditions, such as soil parameters, plot size, lighting, style of the object and budget.

The term «flower bed» is general for any group of ornamental plants. Although flower beds can look diverse in shape and appearance, any composition that includes ornamental plants in a limited and delimited space can be considered a flower bed [2].

Flower beds can be large, medium or small, clear or have natural outlines, ornamental or carpet, ceremonial or seasonal. Using a variety of plant species, such as perennial herbaceous plants, annuals, biennials, ornamental shrubs, trees, conifers and ferns, as well as artificial and natural coverings and lawns, creating a variety of designs [2].

When organizing flower gardens in urban conditions, it is important to take into account certain requirements, such as the poverty of the soil, the size of the plot, the lighting and the style of the garden. The use of methods of enriching the soil with nutrients is an important part of the process of planning and creating long-lasting and bright floral compositions.

When choosing an assortment of plants for a flower garden, one should take into account the endurance of plants to the conditions of the urban environment [7]. For flower gardens in squares and parks, in places remote from roads and protected from the wind, one can use species and varieties of flowering plants that are more demanding on growing conditions. For landscaping the main urban areas (sidewalks, roadsides, areas with high pedestrian traffic), it is better to choose unpretentious plants that can withstand irregular watering, constant shading or, conversely, strong lighting, and air pollution.

Considering that the urban flower garden must maintain its decorativeness for the maximum period of time from spring to late autumn, flower crops for it are chosen taking into account the time of flowering so that they replace each other. In this case, the composition remains in bloom throughout the entire growing season, and its appearance gradually changes [2].

When arranging urban flower gardens, it is recommended to «close» the soil as much as possible. If the surface of the flower garden remains open, it dries out more, is blown away by the winds, and becomes clogged. To prevent this, it is necessary [12]:

- to place flower beds and single-flowered plants on the lawn. In this case, the borders of the flower garden are designed with borders so that the lawn grass does not interfere with the growth of flowers (it comes close to ornamental plants, around which only a small space remains free). The lawn helps to regulate soil moisture and temperature, acts as a filter against pollutants, and protects against blowing;
- to use decorative filling with gravel, pebbles, and coarse sand. This technique is often used when arranging arabesques (patterned, elegant carpet plantings on a plane) and borders.

The border between the soil under ornamental plants and the fill is formed by a border tape, decorative stones or mulch.

It is quite difficult to distinguish between flower beds, islands, groups and rabatkas. However, the basis of any plot is always the simplest constituent elements and basic principles that allow you to create an impression of special expressiveness.

It should be noted that previously the regular style prevailed in the planning of parks and squares. Today, the regular style of flower beds with decorative flower arrangements of a simpler, symmetrical form prevails near landmarks and official buildings. The landscape style of arrangement of green spaces and flower bed design is more popular and widely used.

The landscape style of flower garden design harmoniously combines urban development and natural elements. Expressive and bright objects and groups are created in parks, and small landscapes are recreated on boulevards and squares, taking into account the desire of a person to spend time in nature.

The basic types of flower gardens include those that are quite easy to recognize and distinguish, namely: parade (parterre), flower beds, rabatki, borders, flower beds of carpet plants, striped flower beds, arabesques, mixborders, vases of various materials and compositions of climbing plants – these types of flower gardens will help to form a regular style of any landscaped object [6].

In addition to traditional flower gardens, there are also functional or specific types of flower gardens that are laid out in special conditions, created specifically for individual objects or from specific plant species [7].

Front (or parterre) flower gardens are complex multi-tiered compositions for decorating entrance groups of buildings, central or entrance areas in parks, for squares, public gardens [8]. As a rule, a parterre flower garden is the main composition located in front of the facade of a building, in the center of a street, square, or architectural ensemble (Fig. 1.). It is the central part of the entire garden and park composition, therefore it must be designed in a classical floral and decorative style, adhering to all the laws of decorative gardening. Its components can be lawns, decorative leafy and flower plantings, small architectural forms. A pool or fountain can be located in the parterre part. These flower gardens are designed with regular lines and shapes [4].

Fig. 1. *Parterre flower gardens: a – T.G. Shevchenko Park, Aleksandriya (Kirovohrad region), b – Kropyvnytskyi Arboretum (photo by Boiko T.)*

This type of flower design is often used in parterre gardens, in front of public buildings, in front of parks and large squares, as well as in other plantings in regular planning. These are quite decorative compositions that emphasize the importance and significance of the building in front of which the parterre is planted.

The shape and color scheme of the parterre flower garden should create a single space together with the architectural styles of neighboring buildings located nearby, small architectural forms, conditions and features of the area.

The most modern solution is to create various irregularly shaped figures. The size of the parterre flower garden will primarily depend on the size of the landscaping object and the house that the flower garden decorates, as well as the entire architectural ensemble. The style of the flower garden-parterre can be both landscape-romantic and classical-regular. Such flower gardens are created with bright, large plants with beautiful flowering (tulips, begonias, yuccas, heathers, chrysanthemums).

Rabatki – according to the definition of Kolenkina M.S. «these are flower beds in the form of long, narrow flowering strips placed in parterres along paths, along boulevards, streets and alleys in parks» (Fig. 2) [9].

Fig. 2. *Examples of rabatka on the lawn background (Košice, Slovak Republic) (photo by Boiko T.)*

The length of the rabatka can vary from 3,0-4,0 and even up to ten meters, and the width – from 50,0 to 80,0 cm to 2,0 meters. On one side, the plants are located at two levels – in the foreground – low, and behind – high. The rabatka can be two-sided – when tall plants are planted in the center, and short ones on the sides [9].

The most decorative flower beds are those made of plants of the same height. Flowering plants of one to three colors are planted in rabatka. A large pattern can be repeated several times. Annual, biennial and perennial flower crops are planted in flower beds.

A border is defined by Kolenkina M.S. "this is a narrow strip 10-30 cm wide, in which one or two rows of low-growing flowering plants of a certain species or variety are planted so that they keep their shape well and lend themselves to pruning" [9]. Borders are placed along the edges of flower beds and flower beds in order to emphasize their outlines and create a complete look of the compositions.

A border should perform two main functions. The first is to be sufficiently decorative, the second is to perform the function of a border.

When creating this type of planting, it is worth following several generally accepted rules: use color contrast, high decorative qualities, a margin of space, compliance with classical parameters, compact participants in the border planting [12]:

– the contour of the flowerbed should be clear and bright. Therefore, it is necessary that the main area of the border creates a contrast to the main area of the flowerbed;

– most often, low-growing annuals and perennials are used to create borders. Borders look well-groomed when the plants are planted close to each other and without gaps. However, the plants should not be planted too densely, close to each other, leaving spaces. The plants will grow, so you need to leave some space. Otherwise, the planting will be too dense, where the plants will interfere with each other;

– plants must have high decorative properties. Some flowering plants, after rain or a downpour, lose their attractiveness. Such species are definitely not suitable for flower borders;

– it is important that in any weather and under any circumstances a border of flowering plants looks perfect. Therefore, between a capricious plant and a non-capricious one, it is better to give preference to the second option;

– there are certain standards for borders. And it is extremely important that it meets these standards. For example, the width of such a planting should not exceed 0,5 meters, and the height should not exceed 0,4 meters. Sometimes the fringes can be higher if the plants in the flowerbed are also taller. In addition, there are plants that can be trimmed and thus adjust the height of the border;

– a flower border should always be neat. It is important that the plants grown in it do not grow too large or wither.

Therefore, when choosing flowering plants as borders, preference should be given to those types of flora that do not differ in growth intensity.

Annual flowering plants look bright and quite impressive if they are planted in borders. However, they have a significant drawback: border flower beds created from annual plants must be updated annually or every season (for example, *Tagetes* sp., *Calluna* sp., *Alyssum x hybrida, Lobularia maritima* (L.) Desv.). Perennial plants for border planting are more convenient and versatile (plantings of *Buxus sempervirens* L., *Ligustrum vulgare* L., *Taxus* × *media* Rehder, *Lavandula* x *hybrida*, *Cotoneaster dammeri* C.K. Schneid etc.). Perennial herbaceous plants can be used. With the onset of cold weather, the above-ground parts of these plants die off, and the rhizomes are dormant until spring. So in the new season, only a correction of the «frame» will be required. Such plants include *Chrysanthemum, Allium montanum* ssp., *Ajuga reptans* L., *Sedum ewersii* (Lebed.) H. Ohba, *Dianthus caryophyllus* L. etc.

Carpet flower beds are flower beds with a complex pattern, created using ground cover and carpet plants. Ground cover plants are several classes of plants: creeping shrubs, semi-shrubs and ornamental herbaceous plants (annuals, biennials and perennials). Plants of these classes are characterized by the fact that they have the so-called vegetative mobility - that is, they quickly spread to a new area and hold it behind them. For carpet flower beds, low-growing herbaceous plants (5-15 cm tall) are used, with creeping stems, with variegated colored decorative leaves, characterized by the fact that they lend themselves well to shaping by cutting and pruning. These plants are used in decorative floriculture to create floral ornaments.

Carpet flower beds, despite their decorativeness and effectiveness, are used in landscaping quite infrequently because their creation and care are quite complex, requiring a lot of manual labor and capital investment.

The best plants for such compositions are *Coleus scutellarioides* (L.) Benth., *Cineraria maritima* L., *Sedum reflexum* L., *Pelargonium* × *hortorum* L.H.Bailey, *Salvia splendens* L., *Begonia* x *hybrida, Vinca major* L., *Ipomoea batatas* (L.) Lam., *Thymus serpyllum* L., *Saxifraga x Arendsii* Engl. & Irmsch. etc.

Arabesque is an ancient element of floral design, used both independently and as elements of a flower bed (Fig. 3).

Fig. 3. *Examples of arabesques (https://surl.li/scwzkn)*

The word «arabesque» comes from the Italian word arabesco, which means «Arabic». This is how medieval Europeans called complex and amazing ornaments from the East. The arabesque style, typical of this period, contains a variety of geometric and floral motifs, it can be seen on carpets, walls, ceramics and manuscripts. Then the ornaments began to be used in landscape design, and in Arabic they began to call flower beds of unusual shapes. In order for the arabesque to be clearly visible, the brightest flowers must be planted along the borders of the flower bed. According to the method of execution, arabesques come in different types:

- arabesques, the outline of which resembles the shape of various animals and plants.
- a complex multi-colored ornament of geometric shapes, curls, circles, wavy and broken lines.
- inscriptions or portraits.

Arabesque can be used as an independent flower bed or as part of another type of flower bed, for example, a border or border. Ideal plants for arabesque are carpet plants, which are no more than 15 cm high (*Echeveria* DC., *Antennaria dioica* (L.) Gaerth., *Pelargonium* L'Hér., *Stachys byzantina* K.Koch.).

The best place to place an arabesque is a slight slope – this way the composition will be better visible. Usually, a flower garden in the arabesque style is placed on a flat surface if it will occupy a large area. A wide range of plants can be used to create arabesques – (*Petunia × hybrida, Saxifraga*, *Nasturtium officinale* W.T. Aiton, *Vinca minor*, *Dianthus chinensis* L., *Lobelia x hybrida*, *Festuca gautieri* (Hack.) K.Rickht., *Festuca ovina* L. etc). In the listed species, either the leaves or the flowers are decorative [7, 13-15].

In order to arrange an arabesque, several requirements must be met.

1. First, you need to choose a place on the site. Arabesque can be placed in the garden parterre or in the corners of lawns. Such flower beds look even more advantageous on slopes.

2. It is necessary to create a color scheme of the future composition in advance.

3. After that, transfer the scheme to the selected plot of land.

4. Choose the appropriate plant species. Carpet plants with a height of no more than 15 centimeters are most often used for decoration.

5. It is necessary to select the species composition, guided by the development cycle of plants. Annuals are most often used for arabesques.

6. Plants are planted in the drawn contour in parts.

7. If the arabesque style consists of many different species and colors, it does not need a border. Monotonous compositions are planted with plants of the same species. To make it clearly visible, its contour is made in contrasting colors.

8. Plant patterns can be combined with decorative material: sand, pebbles, gravel, brick or granite chips.

9. Arabesque, like any other flower garden, requires constant care: watering, cutting, thinning.

A mixborder is a flower garden in which several species of plants are planted in a staggered order [2]. Just like the flower border, the mix border has an elongated shape. Its length always exceeds the width by at least 2 times. The length of the flower bed is not limited and can correspond to the length of the path, and the average width is 1,5-2,0 m.

Plants in a mixborder are selected in such a way that their flowering alternates throughout the season, from early spring to late autumn. It is planned that the flowering of the plants will begin in early spring, when the primroses will appear from under the snow, followed by tulips and other bulbous plants, then herbaceous perennials, shrubs and semi-woody bushes, and chrysanthemums and asters will complete the border. Continuity of flowering is achieved by using different types of perennials, which are grouped in several plants. Such groups are distributed in the flower garden at a certain distance, there can be 2-3 or more, depending on the length of the mixborder. It is desirable that the alternating groups of plants differ in the size of the leaves, the shape of the bush, and the shade of the flowers.

Mixborders are one-sided and two-sided. In one-sided flower beds, tall plants are placed in the background, and closer to the viewing point, their height decreases. They are arranged along garden paths, fences, retaining walls. A one-sided mixborder can also be created near the wall of a house or other structure, near a steep slope, on the edge of the garden. When the flower bed is laid out in an open space that can be viewed from several sides, the tallest plants are placed along its center line. Then, as you approach the edges, the height of the plantings decreases according to the cascade principle.

Types of mixborders are divided into:

– in the English style – are distinguished by their restrained execution, based on shrubs with elongated leaves (*Salix babilonica* L., *Caryopteris clandonensis* Bunge) and beautifully flowering perennials, for example, *Paeonia × suffruticosa* Andrews.

– meadows style – consist of herbs and annual flowers, such as *Matricaria chamomilla* L., *Antirrhinum majus* L., *Zinnia elegans* Jac. Du Val, *Linum grandiflorum* Desf., *Papaver rhoeas* L.

– country estate style – when creating which shrubs and flowering plants traditional in rural areas are used: *Viburnum opulus* L., *Malva* sp., *Tagetes erecta* L., *Nasturtium* sp., *Sedum Dazzleberry* L. It is used to create an atmosphere of home comfort. In the rural mixborder it is customary to use garden berries: *Ribes rubrum* L., *Ribes uva-crispa* L., *Amelanchier alnifolia* (Nutt.) Nutt. ex M.Roem;

– garden style – created using garden crops, ornamental, spicy and medicinal herbs. For this style are suitable *Brassica oleracea* var *gongylodes*, *Brassica oleracea* var. *italica*, *Petroselinum crispum* (Mill.) Fuss., *Phaseolus coccineus* L., *Mentha piperita* L., *Mentha spicata* L., *Melissa officinalis* L., *Thymus serpyllum*.

Decorative vases are special structures that allow you to plant plants outside. In addition to this function, such concrete flowerpots can serve as a space divider in an open area. Flower containers and vases are good for decorating windows, balconies, terraces, and stairs. The shape and size of containers can be different. Plants of the same species are usually planted in containers or vases (Fig. 4).

Fig. 4. *Using decorative vases in a parterre flower garden (Alexandria, Kirovohrad region) (photo Boiko T.)*

Vases come in different sizes and shapes. They can be portable, stationary, hinged, simple and avant-garde. A concrete flower garden is perhaps the most popular element of landscape design. With the help of such elements, the general atmosphere of the site is created.

A concrete flower bed is a great way to green the yard if there is a shortage of free space. Such a flower garden is one of the ways of vertical gardening of the city (Fig. 5).

Fig. 5. *Using a concrete flower bed in urban landscaping (Košice, Slovak Republic) (photo by Boiko T.)*

If there are no trees in the yard, you can plant small trees or bushes in vases. The walls of the house can be decorated with hanging flowerpots that droop or weave, for example, *Aristolochia durior* Hill. Decorative vases are also used at the entrance to the building, on both sides of the stairs, along the alleys.

Solitaires are singly planted plants with a particularly decorative bush shape, abundantly blooming, with decorative leaves; single plants that can be used in both regular and landscape types of flower beds. Usually, a large flowering or decorative leafy plant is used as a solitaire. Low, beautiful bushes, such as roses, hydrangeas or spireas, also look good.

In design, tapeworms are used in cases where it is necessary to diversify a large horizontal space. Plants that are selected for tapeworm plantings should be very decorative throughout the entire period from spring to autumn: stems (trunks), leaves, flowers and fruits. The most spectacular are plants with large single flowers or dense large inflorescences consisting of small flowers. The plant should fit well into the surrounding landscape in terms of the color of leaves and flowers.

The background is of great importance for tapeworms: on a neglected lawn, even the most decorative tapeworm is unlikely to look spectacular. Neat lawns and well-formed conifers and shrubs are used as a background for tapeworms.

When placing tapeworms, it is necessary to remember: species with small leaves, with a decorative flower shape, as well as varieties with dark flowers are planted in the foreground, and, conversely, plants with large leaves, large and colorful flowers or inflorescences can be planted in distant areas of the park or garden, since they are well visible from a distance.

Planting perennial climbing plants on the site performs several functions [7, 8].

Climbing plants beautifully decorate fences, arches, arbors, walls of buildings, help to decorate less decorative parts of the park, household elements, wrapping around the walls of the building, the plants will create additional protection for the site from dust and noise pollution.

When choosing creeping perennials for a landscaping object, it is necessary to take into account that they are divided into groups (according to Boyko T. et al. [16]): "those that creep (used for landscaping horizontal surfaces); those that climb (they have special suckers on the stem, with which they attach to vertical surfaces); and those that cling (they require supports)".

Before planting, it is necessary to think over the supporting structures and select them in such a way that they can withstand the weight of the plant. Thin cords, plastic nets can be stretched over plants with thin stems; with thick stems, stronger metal or wooden structures are needed. Some plants, in addition to the support, require special clothespins that will help fix the shoots on the support. The remaining space is either sown with lawn grass, or covered with gravel, wood chips, etc.

A modular flower garden is a floristic composition built on the basis of one element that is constantly repeated, most often of any geometric shape. A modern modular flower garden is a composition of a given geometric shape, filled with plants planted in containers of the same size (Fig. 6).

Fig 6. *Example of modular flower beds https://surl.li/dvsnig*

Such flower beds can become a kind of monoflora, if you plant plants of the same species, but of different varieties, for example, begonias or geraniums in the modules.

Modular flower beds, despite their simplicity, have a very attractive appearance. The area allocated for the flower bed is divided into regular elements of various geometric shapes. In some, flowers (perennials and annuals), a beautiful low bush or low coniferous crops are planted, for example, Juniperus virginiana L. or Microbiota decussate Kom.

They are needed in order to clearly separate the flower bed zone from the path or lawn, to separate different types and varieties of plants in space, for the convenience of combining inert materials (colored gravel) and plants in the composition, to create a carpet pattern in the flower bed.

Modules for flower beds can be made as a metal strip, plastic border, wooden board, sidewalk curb, low concrete or stone fence. Sometimes the edge of a tile or stone path serves as the module boundary. The main condition when creating a module is clear boundaries made of durable materials.

Modules can be placed singly at some distance from each other, or they can be tightly adjacent to each other, forming a single pattern. In this case, when creating a modular flower bed, a given area is divided into regular elements in accordance with the project. The dimensions of the modules are correlated with each other and depend on the size of the composition. A module of a certain size is taken as the basis for creating a modular flower bed. Usually they range from several square decimeters to 1-2 square meters. Modules with plants can be located on a lawn or hard surface (asphalt, paving slabs).

The internal and external boundaries of the modules are often made barely noticeable (metal or plastic strip). Or they can be on the same level with the plants in height, wide enough and painted in contrasting colors (white, red, black, yellow, etc.). Then the modules are made of stone, concrete, wood.

In the landscape style, there is another version of the modular flower garden. It has free contours of the external and internal borders. In this case, against the background of the lawn or on a given border of the flower garden area, a pattern is created using a metal or plastic strip, in which there is no symmetry. In this case, plants of different shapes and heights are used.

Large modules (from 2-3 to 10-20 sq.m.) often have the appearance of parterres or low raised flower beds of the correct shape. Natural stone, concrete, curbstone are used to decorate their borders. Several large rectangular or square containers installed on a hard surface can serve as a modular flower garden.

Another possibility of using modules is patterns on the lawn, when against the background of the lawn using a metal strip, plant patterns are created or symbols of royal power (lily) are depicted, which are filled only with inert materials of contrasting colors (red brick, white gravel, black charcoal). They are used as parterres in palace complexes.

A modular flower garden, like any other, includes a variety of plants. It is very important when creating it to develop a flower garden project with a reference to a specific place, to determine its size and shape. Depending on the type of modular flower garden, its style, and size, the necessary plants are selected.

Small square modules or containers are often filled with a monoculture – one species and variety of plants. These can be low-growing annuals (*Alyssum saxatile*, *Dianthus caryophyllus* L., *Sedum sieboldii* L., *Salvia officinalis* L.), bulbous plants for spring compositions (*Tulipa, Narcissus, Muscari, Hyacinthus*), compact perennials (species of the genus *Hosta, Begonia tuberosa* or *Begonia semperflorens* , *Astilbe chinensis* (Maxim.) Franch. & Sav., species of the genus *Dahlia, Phlox, Heuchera, Iris, Bergenia*), spicy-aromatic plants (*Thymus serpyllum*, *Origanum vulgare* L., *Hyssopus officinalis* L., *Rosmarinus officinalis* L., *Lavandula angustifolia* Mill., *Satureja* sp., *Levisticum officinale* W.D.J.Koch), any vegetable crops [7, 15-19].

Roses, dwarf conifers, small bushes, rhododendrons are planted in large modules. Such modules are good for collection plants - alpine, spicy-aromatic, medicinal and others. Sometimes modules filled with plants alternate with modules with white or colored gravel.

Arrays are a large-sized flower arrangement, the most popular flower arrangement in landscape parks. They can occupy an area of 80 to 150 m^2. The greatest decorative and compositional effect of the paintings is when placed on park lawns with an area of 800-1000 m^2 or more. Only in this case is the space of the designed composition felt. Large works are always moved at certain distances. The paintings are created from perennial plants, sometimes annual flowers are included in their composition. Rows of single-colored perennials in combination with bushes with beautiful flowers or decorative foliage make a good impression: a fan of purple-blue muscari flowers against a background of sunny-yellow forsythia flowers; dark pink peonies and blue delphiniums against a background of snow-white garden jasmine, etc. When planting such arrays, they are given an artistic, graceful shape, winding contours to create a play of light and shadow, volume and depth. According to Kucheryavy V.P. [1], groups are “the most common and quite effective type of floral design, which looks both neat and natural, especially when the group is located on a green lawn”. The area of the groups can be different, as well as their configuration. Plant groups can consist of perennials, often in combination with biennials or annuals that begin to bloom after bulbous perennials (tulips, crocuses, daffodils) bloom. Groups of large plants of the same species or genus will look quite impressive, for example, from different varieties of astilbe, hydrangeas, lupines, marigolds. Plants of contrasting shapes are often used for the background: hosts and geyheras, cineraria.

The groups are placed closer to the viewer than the picture. We distinguish between simple and complex groups.

Separate simple groups are created from plants of the same species and selected in such a way that the plants in them bloom one after the other.

When planning nested groups, plants of different life forms can also be combined. In this case, the main attention is focused on the height of the plants. The placement of different plants in the group depends on how the group itself is located.

If it is visible from all sides, then tall plants are placed in the center, and low ones are placed on the periphery.

If the group planting is placed close to a wall or fence, tall plants should be placed in the background, and low ones in the foreground. Groups look better when they are connected by a clear geometric shape. The size of groups can be from 3.0-5.0 to 15.0-25.0 and even up to 40.0-50.0 m^2. Groups in parks are created mainly from perennial, occasionally from annual flowers.

Flowering or Moorish lawns are unpretentious flower beds, which are a “flowering meadow” of low-growing cereal grasses and flowering meadow grasses - daisies, cornflowers, poppies, lupins, bells, etc. [2]. The species composition of plants on such lawns is tried to be selected in such a way that they bloom, replacing each other throughout the season. Moorish lawns, as a rule, are not mowed.

Outwardly, they resemble wild meadows, which abound in a variety of flowers. If you skillfully choose different plants and their varieties, the lawn will bloom all summer.

Flowering plants among lawns grow well and develop, occupying large spaces that resemble flower meadows. Perennial flowering lawns are created on existing lawns by planting perennial flowering plants in groups or individually. Here you can use chrysanthemums, bluebells, mallows, etc. [7].

To form a flowering lawn, poor but well-drained soil is enough. A feature of these lawns is a simple and organic combination of grass and flowers. Previously, in city parks, they tried to divide them, plant separate lawns and arrange separate flower beds. To create such a flower garden, you need to have spacious lawns in parks or relatively large areas of lawns. In landscape parks, you can always find such a lawn to demonstrate this striking richness of colors and a completely natural type of flower garden design.

Features of creating flower beds in green areas of the city of Kropyvnytskyi

Creating flower beds is a rather complicated and painstaking process, because it is necessary to take into account the combination of different plants and their characteristics and the principles of constructing compositions. To do this, it is necessary to pay attention to the lifespan of certain plants, their attitude to moisture and light, flowering time, compatibility with other representatives and the features of care [6].

The main principle that should be guided when designing a flower bed is the subordination of floral design to the general purpose of this landscaping object. For the most complete and vivid manifestation of the characteristics of flowers and plants used in landscaping, one can be guided by the main classical styles. There are regular and landscape styles [4].

Basic rules for creating flower beds [7]:

1. At the planning stage, it is important to outline the approximate contour of the future flower bed, determine its location and shape. Using plants of different colors, we can display the flowering zone and determine the height of the plants. The contrast between the flowers and the surrounding landscape should be considered, as well as the timing of flowering.

2. When planting plants, it is important to follow a sequence so that the flower garden blooms throughout the season. The use of perennial flowering plants such as *Festuca ovina*, *Gaillardia arizonica* A.Gray, *Gaillardia x grandiflora* Hort. ex Van Hourtte, *Viola tricolor* L., *Malva grossheimii* Schischk., *Hemerocallis* L., *Geranium sanguineum* L. will help ensure continuous flowering. You should also avoid shading plants from each other and create a harmonious flowering pattern.

3. A balanced combination of different flower shades plays a key role. It is important to distinguish between the dominant, background and neutral color tones of the flower bed. Such a combination should harmoniously fit into the landscape and create positive emotions.

4. When arranging plants, you should be guided by the principle of a “multi-tiered pyramid”. Place the tallest flowers in the center or background of the composition, the middle ones closer to them, and the shortest or ground covers in the foreground. This will allow each plant to receive enough sunlight, avoid shading, and create contrast between tall and short plants.

5. Maintaining the optimal distance between flowers guarantees the provision of the necessary nutrients and space for healthy growth. According to the recommendations, on 1 m² of flowerbed, placing from seven to ten low-growing plants, four to seven medium-sized and one to three types of tall plants is optimal. Such a distribution will help avoid diseases and ensure a holistic appearance of the flower bed.

6. It is important to select the species diversity of flower plants taking into account their viability and biological requirements. The ability of plants to compete for nutrients can determine their decorative appearance on the site. Thus, you should avoid planting plants with different light requirements in the same zone, giving heliophytes and sciophtes separate areas of the area.

7. The border for the flower bed performs an important function, giving the flower bed a complete and aesthetic appearance. This edging not only defines the boundaries of the flower bed, but also performs a protective role, preventing weathering and soil erosion. The choice of material for a border can be varied, including brick, stone, wood, metal, plastic, or even original options such as a fence made of glass bottles or a border of ground cover flowers. The use of mulch will improve its functionality and appearance.

Species diversity of flower gardens in Kropyvnytskyi

61 plant species belonging to 42 genera and 30 families have been identified in the flower gardens of Kropyvnytskyi (Table 1). The most numerous are representatives of the families *Asteraceae* Dum. (eight species), *Liliaceae* Juss. (six species), *Cupressaceae* (six species), *Lamiaceae* Lindl. (five species), *Crassulaceae* DC. (three species), *Geraniaceae* Juss. (three species). Other families are represented by one or two species. There are 15 species of annual plants, 49 species of perennials [1].

Table 1. Taxonomic diversity and biomorphological features of flower gardens in Kropyvnytskyi

№	Species name	Family	Life form	Vegetation type	Recommendations for use
1.	*Ageratum houstonianum* Mill.	*Asteraceae* Dum.	perennial	summer green	groups, flower beds, the borders
2.	*Ajuga reptans* L.	*Lamiaceae* Lindl.	perennial	summer green	groups, flower beds, the borders
3.	*Coleus scutellarioides* (L.) Benth.	*Lamiaceae* Lindl.	annual	summer green	groups, flower beds, the borders
4.	*Begonia semperflorens* hort.	*Begoniaceae* Agardh	annual	summer green	groups, flower beds, the borders
5.	*Berberis vulgaris* L.	*Berberidaceae* Torr. et Gray.	ornamental deciduous shrub	deciduous	groups, flower beds, the borders, the borders
6.	*Berberis thunbergii* DC.	*Berberidaceae* Torr. et Gray.	ornamental deciduous shrub	deciduous	groups, flower beds, the borders, the borders
7.	*Buxus sempervirens* L.	*Buxaceae* Dumort.	ornamental deciduous shrub	evergreen	groups, flower beds, the borders
8.	*Cineraria maritima* L.	*Asteraceae* Dum.	annual	summer green	groups, flower beds, the borders
9.	*Dianthus deltoids* L.	*Caryophyllaceae* Juss.	perennial	summer green	groups, flower beds, the borders
10.	*Dianthus barbatus* L.	*Caryophyllaceae* Juss.	perennial	summer green	groups, flower beds, the borders
11.	*Dianthus caryophyllus* L.	*Caryophyllaceae* Juss.	perennial	summer green	groups, flower beds, the borders
12.	*Delphinium elatum* L.	*Ranunculaceae* Juss.	perennial	summer green	groups, flower beds, plants background
13.	*Gaillardia* x *hybrida* Kobold.	*Asteraceae* Dum.	perennial	summer green	groups, flower beds, the borders
14.	*Hosta hybridum*	*Liliaceae* Juss.	perennial	summer green	groups, flower beds, the borders, plants background
15.	*Hosta fortune* L.	*Liliaceae* Juss.	perennial	summer green	groups, flower beds, the borders, plants background
16.	*Hosta sieboldiana* L.	*Liliaceae* Juss.	perennial	summer green	groups, flower beds, the borders, plants background
17.	*Hylotelephium spectabile* (Boreau) H.Ohba	*Crassulaceae* DC.	perennial	summer green	groups, flower beds, the borders
18.	*Jucca filamentosa* L.	*Liliaceae* Juss.	ornamental leafy perennial plants	evergreen	groups, flower beds, the borders, the borders
19.	*Juniperus sabina* L.	*Cupressaceae* Bartl.	ornamental deciduous shrub	evergreen	the borders, groups, flower beds, the borders
20.	*Juniperus sabina 'Tamariscifolia'*	*Cupressaceae* Bartl.	ornamental deciduous shrub	evergreen	the borders, groups, flower beds, the borders
21.	*Juniperus virginiana* L.	*Cupressaceae* Bartl.	ornamental deciduous tree	evergreen	the borders, groups, flower beds, the borders

№	Species name	Family	Life form	Vegetation type	Recommendations for use
22.	*Juniperus virginiana* '*Blue Arrow*'	*Cupressaceae* Bartl.	ornamental deciduous tree	evergreen	the borders, groups, flower beds, the borders
23.	*Juniperus horizontalis* Moench. '*Forest Blue*'	*Cupressaceae* Bartl.	Ornamental deciduous shrub	evergreen	the borders, groups, flower beds, the borders
24.	*Juniperus horizontalis* '*Prince of Wales'*	*Cupressaceae* Bartl.	Ornamental deciduous shrub	evergreen	the borders, groups, flower beds, the borders
25.	*Elymus arenarius* (L.) Hochst.	*Poaceae* Mash	perennial	summer green	groups, flower beds, the borders, plants background
26.	*Iris hybrida* hort.	*Iridaceae* Juss.	perennial	Summer green, beautiful-flowering	groups, flower beds, the borders, the borders
27.	*Iris pumila* L.	*Iridaceae* Juss.	perennial	Summer green, beautiful-flowering	groups, flower beds, the borders, plants background
28.	*Kochia scoparia* (L.) Schrad.	*Amaranthaceae* Juss.	annual	summer green	the borders, groups, flower beds, the borders
29.	*Lupinus arboreus* Sims.	*Fabaceae* Lindl.	perennial	summer green	rabatkas, groups, the borders, flower beds
30.	*Ligustrum vulgare* L.	*Oleaceae* Lindl.	ornamental leafy perennial plants	deciduous	groups, flower beds, the borders, hedges, the borders
31.	*Lobelia erinus* L.	*Campanulaceae* Juss.	perennial	summer green	groups, flower beds, the borders, plants background
32.	*Malva moschata* L.	*Malvaceae* Juss.	perennial	summer green	groups, flower beds, the borders, the borders
33.	*Muscari botryoides* (L.) Mill.	*Asparagaceae* Juss.	perennial	summer green	groups, flower beds, the borders
34.	*Muscari pycnanthum* C.Koch.	*Asparagaceae* Juss.	perennial	summer green	groups, flower beds, the borders
35.	*Narcissus hybridus* hort.	*Amaryllidaceae* J.St.-Hil.	perennial	summer green	groups, flower beds, the borders
36.	*Ocimum basilicum* L.	*Lamiaceae* Lindl.	annual	summer green	groups, flower beds, the borders
37.	*Pelargonium peltatum* (L.)	*Geraniaceae* Juss.	annual	summer green	rabatkas, groups, flower beds, the borders
38.	*Pelargonium zonale* Wild.	*Geraniaceae* Juss.	annual	summer green	rabatkas, groups, flower beds, the borders
39.	*Pelargonium × horto rum* L.H.Bailey	*Geraniaceae* Juss.	annual	summer green	rabatkas, groups, flower beds, the borders
40.	*Petunia* x *hybrida* Vilm.	*Solanaceae* Juss.	annual	summer green	rabatkas, groups, flower beds, арабески
41.	*Phlox paniculata* L.	*Polemoniaceae* Juss	perennial	summer green	rabatkas, groups, flower beds, the borders

№	Species name	Family	Life form	Vegetation type	Recommendations for use
42.	*Phlox subulata* L.	*Polemoniaceae* Juss	perennial	summer green	rabatkas, groups, flower beds, the borders
43.	*Primula veris* L.	*Primulaceae* Vent.	perennial	summer green	rabatkas, groups, flower beds, the borders
44.	*Rudbeckia laciniata* L.	*Asteraceae* Dum.	perennial	summer green	rabatkas, groups, flower beds, the borders
45.	*Salvia officinalis* L.	*Lamiaceae* Lindl.	perennial	summer green	rabatkas, groups, flower beds, the borders
46.	*Salvia splendens* L.	*Lamiaceae* Lindl.	annual	summer green	rabatkas, groups, flower beds, the borders
47.	*Sonecia cineraria* L.	*Asteraceae* Dum.	annual	summer green	rabatkas, groups, flower beds, the borders
48.	*Sedum acre* L.	*Crassulaceae* DC.	perennial	summer green	rabatkas, groups, flower beds, the borders
49.	*Sedum reflexum* L.	*Crassulaceae* DC.	perennial	summer green	rabatkas, groups, flower beds, the borders
50.	*Spiraea media* F.Schmidt	*Rosaceae* Juss.	ornamental deciduous, beautifully flowering shrub	deciduous	groups, flower beds, the borders, hedges, the borders
51.	*Spiraea* x *vanhouttei* (Briot) Zab.	*Rosaceae* Juss.	ornamental deciduous, beautifully flowering shrub	deciduous	groups, flower beds, the borders, hedges, the borders
52.	*Tagetes patula* L.	*Asteraceae* Dum.	annual	summer green	groups, flower beds, the borders
53.	*Tagetes erecta* L.	*Asteraceae* Dum.	annual	summer green	groups, flower beds, the borders
54.	*Tulipa hybridus* L.	*Liliaceae* Juss.	perennial	summer green	groups, flower beds, the borders
55.	*Tulipa gesneriana* L.	*Liliaceae* Juss.	perennial	summer green	groups, flower beds, the borders
56.	*Thuja occidentalis* L. ‘*Danica*’	*Cupressaceae* Bartl.	ornamental deciduous shrub	evergreen	groups, flower beds, the borders, hedges, the borders
57.	*Verbena supina* L.	*Verbenaceae* J.St.-Hil.	annual	summer green	groups, flower beds, the borders
58.	*Vinca minor* L.	*Apocynaceae* Juss.	ground cover perennial	evergreen	groups, flower beds, the borders
59.	*Vinca major* L.	*Apocynaceae* Juss.	ground cover perennial	evergreen	groups, flower beds, the borders
60.	*Zinnia elegens* Jacq.	*Asteraceae* Dum.	annual	summer green	groups, flower beds, the borders
61.	*Phytolacca americana* L.	*Phytolaccaceae* R.Br.	perennial	summer green	groups, flower beds, the borders

An analysis of the species diversity of flower gardens in Kropyvnytskyi revealed that the most common annuals in the floral design of the central part of the city are *Petunia x hybrida* Vilm., *Coleus scutellarioides* (L.) Benth., *Tagetes erecta* L., *Begonia semperflorens* hort., *Cineraria maritima* L., *Kochia scoparia* (L.) Schrad., *Pelargonium peltatum* (L.), *Pelargonium zonale* Wild., *Pelargonium × hortorum* L.H.Bailey, *Salvia splendens* L. and *perennials Salvia officinalis* L., *Gaillardia x hybrida* Kobold., *Sedum reflexum* L., *Hylotelephium spectabile* (Boreau) H.Ohba, *Tulipa hybridus* L., *Iris hybrida* hort., *Muscari botryoides* (L.) Mill.. The projective coverage of flower gardens is dominated by plants with decorative foliage, as well as annual plants that form decorative flowers or inflorescences. The borders of some parterre flower beds are surrounded by clipped borders of *Berberis vulgaris* L., *Berberis thunbergii* DC., *Buxus sempervirens* L., *Ligustrum vulgare* L., *Spiraea media* F.Schmidt, *Spiraea x vanhouttei* (Briot) Zab., *Juniperus sabina* L., *Juniperus sabina* 'Tamariscifolia', *Juniperus virginiana* L., *Juniperus virginiana* 'Blue Arrow', *Juniperus horizontalis* Moench. 'Forest Blue', *Juniperus horizontalis* 'Prince of Wales', *Thuja occidentalis* L. 'Danica'.

During the studied period, an arabesque in the form of embroidery was created in the central part of the city on Heroes' Square on the Maidan (Fig. 7), from varietal plants of hybrid petunia, shield-shaped coleus and hybrid iris.

Fig. 7. *Arabesques on Heroes of Maidan Square in Kropyvnytskyi a – 2022, b – 2023*

During the same period, a flowerbed in the form of the coat of arms of Ukraine was created (Fig. 8). The elements of the coat of arms were created using *Coleus scutellarioides* (L.) Benth. *varieties 'Cantigny Royale'* and '*Gold*' and *Cineraria maritima* L. were used to create it.

Fig 8. *Flower garden "Herb" on Soborna Street, a - immediately after planting, b - in the summer of 2023*

Experiments with the use of varietal plants of the genus *Coleus* Lour. in flower arrangements, which were carried out in recent years, allowed us to identify their relative drought resistance, which allows them to be planted in flower beds in open areas. The natural and climatic features of Kropyvnytskyi allow plants of the genus *Coleus* to maintain their decorative appearance until the end of October.

A fairly wide variety of flower plants are characterized by flower beds in the inter-quarter landscaping of the city. In the flower gardens near the houses, in addition to the above, we identified the annuals *Verbena supina* L., *Ocimum basilicum* L., *Tagetes patula* L., *Sonecia cineraria* L., *Zinnia elegens* Jacq.; perennials *Ageratum houstonianum* Mill., *Ajuga reptans* L., *Dianthus deltoids* L., *Dianthus barbatus* L., *Dianthus caryophyllus* L., *Delphinium elatum* L., *Phlox paniculata* L., *Phlox subulata* L., *Sedum acre* L., *Elymus arenarius* (L.) Hochst., *Muscari pycnanthum* C.Koch., *Primula veris* L., *Iris hybrida* hort., *Iris pumila* L., *Rudbeckia laciniata* L., *Tulipa gesneriana* L., *Hosta hybridum*, *Hosta fortune* L., *Hosta sieboldiana* L., *Narcissus hybridus* hort., *Salvia officinalis* L., *Vinca minor* L., *Vinca major* L., *Phytolacca americana* L., *Lobelia erinus* L., *Malva moschata* L. *Iberis sempervirens* L., *Yucca filamentosa* L., as well as *Hydrangea arborescens* L., *Paeonia bushes* can be found in the flower gardens suffruticosa L., various species and varieties of the genus *Rosa* L.

Among all the flower arrangements in the city, the most spectacular are the flower gardens in the central part of the city, such as in front of the city council building, Cathedral Square, Theater Square, Taras Shevchenko Square, and Bohdan Khmelnytskyi Square (Fig. 9). In the Dendropark recreation park in 2023, the flower arrangements were impressive in their decorativeness in April and early May, when the tulips bloomed [20].

Fig. 9. *Condition of flower gardens in Kropyvnytskyi: a – flower garden on Patsaeva Street, b – flower garden in front of the city council, c – flower garden on Chykalenko Street.*

However, after their flowering, new plants were not planted in free areas, which led to a sloppy appearance of the flower beds. Within the framework of the improvement of the Fortechny district, the intra-quarter zones and house areas are at a high level, which leads to a well-groomed appearance of the flower beds [20].

According to the conducted research, it was found that in Kropyvnytskyi, annual plants or perennials used as annuals are often used for landscaping the main streets and park plantings, for example, ivy-leaved pelargonium and sea cineraria. These plants require regular care, annual renewal and cleaning at the end of the season. In particular, it is difficult to find a full-fledged decorative replacement on the main streets.

However, for park plantings, it is proposed to increase the use of perennial plants, such as *Lavandula x hybrida* and *Lavandula angustifolia*, which are adapted to the climate of arid regions and have a long flowering and decorative appearance throughout the year.

Almost not used in the landscaping of Kropyvnytskyi are grasses, which can be a worthy replacement for many annuals and perennials. Among this group of plants, one can distinguish both low-growing species such as *Pennisetum alopecuroides* (L.) Spreng., *Festuca glauca* Vill. '*Elijah Blue'*, and tall *Miscanthus sinensis* Andersson, *Panicum virgatum* L., *Elymus arenarius* [20], which will allow them to be combined in various flower plantings, combined with traditional flower crops, and combined with evergreen and deciduous background plants.

The climbing perennial *Ipomoea batatas* (L.) Lam has become widespread in the cities of Ukraine and Europe. Its varieties with different leaf colors are planted in flowerbeds, as well as for decorating near-stem circles. *Thymus vulgaris* L. and *Sedum lydium* Boiss are also suitable for these purposes.

The trend of landscaping is also the introduction of medicinal and aromatic plants into landscaping, which are often used in private landscaping and are not planted at all in street landscaping in Kropyvnytskyi [4, 7]. We propose to introduce such plant species as *Helichrysum italicum* Guss., *Mentha piperita* L., *Thymus vulgaris* L., *Verbena officinalis* L., etc.

Analysis of flower arrangements in the city of Kropyvnytskyi

There are 40 flower gardens in the city. 270 thousand plants were grown for them.

During the studied period, it was planned to plant 271,700 plants in 40 flower gardens in the city with an area of 1.13 hectares.

More than 50,000 seedlings of flowering plants were planted on 2,000 m^2 of flower beds in the city: petunias, coleus, irises, etc.

The total area of the city's flower gardens, which are located in public greening facilities, is 11,310 m^2. The areas of flower gardens in the city of Kropyvnytskyi in table 2.

Table 2. The area of different types of flower gardens in the city of Kropyvnytskyi (which are subordinate to the communal enterprise «Blagoustriy»)

№	Object name	Area, m²
1	Alley between Volkova and Patsaeva streets	930
2	Alley between Kosmonavta Popova and General Zhadov streets	687,5
3	Velyaka Perspektivna street (Barva store)	55
4	Velyka Perspektivna St. (Kyiv Hotel)	25
5	Velyka Perspektivna St. (Mida Store)	6
6	Velyka Perspektivna St. (descent)	292
7	Velyka Perspektivna St. (treasury)	133
8	Velyka Perspektivna St. (Ukrtelecom)	16
9	Geroiv Ukrainy St. (Alley of Glory, Rivne Cemetery)	44

№	Object name	Area, m²
10	Gogolya St. (near MVK)	4
11	Yevhena Chykalenko St.	470
12	Kavaleriiska St. (Philharmonic Hall)	336
13	Soborna St.	530
14	Ushakova St. (Monument to Kuropyatnikov)	16
15	Ushakova St. (Monument to the Victims of the Holodomor)	90
16	Ushakova St. (Cannons)	11
17	Shevchenko St.	8
18	Shevchenko St./Perspektivna St. (Privatbank)	5
19	Historical and Memorial Complex of the Fortress «St. Elizabeth»	1202
20	Historical and Memorial Complex of the Fortress "St. Elizabeth" (Victims of Fascism Square)	500
21	near the 101st microdistrict	1512
22	near the airport	900
23	Kryvyi Rih Entrance	58
24	Tank Memorial	110
25	Park-Monument of Landscape Art of Local Importance «Kovalivskyi» Park	678
26	«Molodyzhny» Park	110
27	«Theatralna» Square	168
28	Heroes of Maidan Square	560
29	Square in front of the MVK	129
30	Soborna Square	334
31	Vynnychenko Avenue	315
32	Fighters for the Freedom of Ukraine Square	12
33	First Elisavetgrad Tram Square	135
34	Prikordonniki Square	12
35	Fountain Square	29,5
36	Chernobyl Square	104
37	Anatoly Buzuljak Square	96
38	Khmelnytsky Square	387
39	Shevchenko Square	288
40	Yanovsky Square	12
Total		11310

Studies conducted in the city have shown that the city's flower beds are represented by parterre flower beds, flower beds of various geometries, flower beds and ornaments (arabesques), as well as modular flower beds.

The vast majority of flower beds are made in a regular style. These are mainly rectangular flower beds, as well as in the form of a circle. The largest flower beds in the city by area are the flower garden in the 101st microdistrict (1512 m^2), the flower garden on the alley between Volkova and Patsaeva streets (930 m^2), the flower garden near the airport (900 m^2), the flower garden between

Kosmonavta Popova and Generala Zhadova streets (687.5 m^2), the flower garden in the park-monument of landscape art of local importance, the Kovalivskyi park (678 m^2), the flower garden on Heroes of Maidan Square (560 m^2) (Table 2). Other flower gardens have much smaller areas.

All flower beds in Kropyvnytskyi are polychrome in color. Their color scheme and ornamentation change every year depending on the designer's ideas, as well as on the grown assortment of seedlings.

102 hanging flowerpots and 14 installations with flowers were installed in the squares in front of the City Executive Committee, Heroes of Maidan, Teatralna, and in the Khmelnytskyi Square. The use of modular flower beds is becoming more popular every year, so their area is planned to be increased.

In general, the floral design of Kropyvnytskyi parks is quite diverse, floral design is presented in every microdistrict of the city. Expanding the assortment of perennials will allow reducing the costs of caring for them.

Conclusions

According to the conducted research, 61 species of plants belonging to 42 genera and 30 families have been identified in the flower plantations of the city of Kropyvnytskyi. The most numerous are representatives of the families *Asteraceae* Dum. (eight species), *Liliaceae* Juss. (six species), *Cupressaceae* (six species), *Lamiaceae* Lindl. (five species), *Crassulaceae* DC. (three species), *Geraniaceae* Juss. (three species). Other families are represented by one or two species. There are 15 species of annual plants, 49 species of perennials.

An analysis of the species diversity of flower gardens in Kropyvnytskyi revealed that the most common annuals in the floral design of the central part of the city are *Petunia x hybrida* Vilm., *Coleus scutellarioides* (L.) Benth., *Tagetes erecta* L., *Begonia semperflorens* hort., *Cineraria maritima* L., *Kochia scoparia* (L.) Schrad., *Pelargonium peltatum* (L.), *Pelargonium zonale* Wild., *Pelargonium × hortorum* L.H.Bailey, *Salvia splendens* L. and perennials *Salvia officinalis* L., *Gaillardia x hybrida* Kobold., *Sedum reflexum* L., *Hylotelephium spectabile* (Boreau) H.Ohba, *Tulipa hybridus* L., *Iris hybrida* hort., *Muscari botryoides* (L.) Mill.. The projective coverage of flower gardens is dominated by plants with decorative foliage, as well as annual plants that form decorative flowers or inflorescences. The borders of some parterre flower beds are surrounded by clipped borders of *Berberis vulgaris* L., *Berberis thunbergii* DC., *Buxus sempervirens* L., *Ligustrum vulgare* L., *Spiraea media* F.Schmidt, *Spiraea x vanhouttei* (Briot) Zab., *Juniperus sabina* L., *Juniperus sabina* ‘Tamariscifolia’, *Juniperus virginiana* L., *Juniperus virginiana* ‘Blue Arrow’, *Juniperus horizontalis* Moench. ‘Forest Blue’, *Juniperus horizontalis* ‘Prince of Wales’, *Thuja occidentalis* L. ‘Danica’.

Among all the flower arrangements of the city, the most spectacular are the flower beds in the central part of the city, such as in front of the city council building, Cathedral Square, Theater Square, Taras Shevchenko Square, and Bohdan Khmelnytskyi Square.

The vast majority of flower beds are made in a regular style. Mostly these are rectangular flower beds, as well as in the form of a circle. The largest flower gardens in the city by area are the flower garden in the 101st microdistrict (1512 m^2), the flower bed on the alley between Volkova and Patsaeva streets (930 m^2), the flower garden near the airport (900 m^2), the flower bed between Kosmonavta Popova and Generala Zhadova streets (687.5 m^2), the flower garden in the park-monument of local significance, the Kovalivskyi park (678 m^2), the flower garden on Heroes of Maidan Square (560 m^2). Other flower gardens have much smaller areas.

All flower gardens in Kropyvnytskyi are polychrome in color. Their color scheme and ornamentation change every year depending on the designer's ideas, as well as the range of seedlings planted.

In the squares in front of the City Executive Committee, Heroes of Maidan, Teatralna, in the square named after Khmelnytskyi, 102 hanging flowerpots and 14 installations with flowers were installed. The use of modular flower beds is becoming more popular every year, so their area is planned to be increased.

REFERENCES

1. Kucheriavyi V.P., Kucheriavyi V.S. (2019). Landscaping of populated areas. 666 p.
2. Ishchuk L.P., Oleshko O.H., Cherniak V.M., Kozak L.A. (2014). Floriculture. za red. kand. biol. nauk L.P. Ishchuk. Bila Tserkva. 292 p.
3. Ishchuk L.P. (2012). Analysis of floral plantation state in bila tserkva and methods of their improvement. Ahrobiolohiia. №8. 78-82.
4. Dobrochaeva, D.N., Kotov, M.I., Prokudin, Iu.N., Barbarich, A.I., Chopik, V.I., et al. (1999). Determinant of higher plants of Ukraine. 1999. Kiev: Scientific thought.
5. Bessonova V.P. (2010). Flower garden plants. Directory. 176 p.
6. Bessonova V.P., Yakovlieva-Nosar S.O., Ivanchenko O.Ie. (2022). Analysis of flower gardens in the parks and squares of the right bank of the Dnipro city. Naukovyi visnyk NLTU Ukrainy. T. 32. № 1. 51-61.
7. Boiko T., Boiko P. (2024). Landscape Designer's Handbook: A Study Guide. Oldie +. 196 p.
8. Bogdanova V.D., Sleptsov Y.V. (2019). Floriculture in closed soil: education. guide Kharkiv: Folio, 186 p.
9. Kolenkina M.S. (2020). Floriculture: lecture notes for full-time students of the educational level «bachelor» in the specialty 206 - Horticulture. Kharkiv. National University of Urban Economics named after O. M. Beketov. KhNUMG named after O. M. Beketov. 202 p.
10. Pushkar V.V. (2007). Dyzain kvitnykiv: navch. posibn. [Flower garden design: atextbook] 336.
11. Shuma O.V., Horbenko N.Ie. (2014). Classification of flower gardens in the central part of the city of Lviv. № 24.11. 94-97.
12. Prokopchuk V.M., Mazur V.A. (2011). Ornamental gardening and floriculture. Study guide. Vinnytsia. 120 p.
13. Boiko T.O., Kotovska Y.S. (2023). The use of perennial cereal crops in landscaping the city of Kherson. Agrarian innovations. №. 17. 7-12.
14. Dementieva O.I., Boiko T.O. (2021). Peculiarities of using perennial medicinal plants in the design of flower gardens in the city of Kherson. Tavria Scientific Bulletin. №118. C. 333–340.
15. Melnyk T.I., Surgan O.V., Drobilko V.M. (2014). Use of petunia hybrida in container gardening. Bulletin of the Sumy National Agrarian University. Series: Agronomy and Biology. (3). 92-95.
16. Boiko T.O., Dementieva O.I., Kotovska Yu.S. (2019). Assessment of biological and ecological properties of woody vines in the conditions of the city of Kherson. Scientific Bulletin of the National Technical University of Ukraine. 29. 31-35.
17. Markovska O.Ie., Svydenko L.V., Stetsenko I.I. Porinal assessment of morphometric indicators and economically valuable traits of *Lavandula angustifolia* Mill. and *Lavandula hybrid* Rev. Naukovi horyzonty. 2020. №02(87). 24-31.
18. Markovska O.Ie., Stetsenko I.I. (2020). Comparative characteristics of narrow-leaved lavender (*Lavandula angustifolia* Mill.) and lavandin (*Lavandula hybrida* Reverenon). 361-365.
19. Svydenko L.V., Markovska O.Y., Stetsenko I.I. (2021). Creation of new perspective cultivars of *lavandula angustifolia* Miil. for growing of area of Ukrainian South. Slovak University of Agriculture in Nitra.
20. Boiko T.O., Vorona A.M. (2023). Analysis of the state of flower arrangement of the city of Kropyvnytskyi and ways of improvement. Bulletin of the Uman National University of Horticulture. №2. 71-76.

FOREIGN EXPERIENCE IN PLANNING HORTICULTURAL AND PARK MANAGEMENT TAKING INTO ACCOUNT INNOVATIVE ACTIVITIES

Nataliya Stoyanets
Doctor of Economic Sciences, Professor, Sumy National Agrarian University, Ukraine
ORCID ID: 0000-0002-7526-6570

Scientific justification of the introduction of new species of ornamental plants and their adaptation to local conditions is an important direction of modern botanical research. Of particular interest are perennial flowering plants, which can become the basis for the creation of stable and durable plant groups. The formation of the assortment of ornamental plants in garden centers is a complex process that requires in-depth knowledge of the biological characteristics of plants, climatic conditions of the region and consumer needs. Horticulture is an important branch of agriculture, providing the population with fresh fruits, vegetables and ornamental plants. Effective planning of horticultural production plays a key role in ensuring high productivity, product quality and economic feasibility. Studying and adapting advanced foreign experience in this area is relevant for increasing the efficiency of domestic horticulture.

If we consider the current trends in European gardening, they reflect the growing attention to environmental friendliness, sustainability and harmony with nature. The main key trends are environmental friendliness and sustainable development, namely the use of local plants that are better adapted to climatic conditions and require less care, the introduction of rainwater harvesting systems and economical irrigation, the use of environmentally friendly materials for paving paths, building benches and other garden elements. Green spaces play an important role in absorbing carbon dioxide and maintaining biological diversity.

Gardens for biodiversity creating conditions for attracting wild animals and insects, such as bees, butterflies and birds, the use of flowering meadows, hedges and plantings that attract pollinators, the creation of "wild" areas of the garden where plants grow without human intervention. Naturalistic landscapes are the rejection of strict geometric shapes in favor of freer and smoother lines, the creation of gardens that imitate natural landscapes such as forests, meadows and water bodies, the use of natural materials such as stone and wood. Vertical gardening is through the use of vertical surfaces to create green walls and gardens, especially relevant for urban spaces where land area is limited. Vertical gardening not only decorates buildings, but also improves air quality and reduces temperatures. Creating public gardens and parks where people can relax, socialize and grow food, arranging roofs and balconies to create small gardens. Such spaces improve the quality of life in cities and promote social interaction. The use of modern technologies, namely the introduction of automatic irrigation and lighting systems, the use of applications for planning and maintaining the garden, the use of drones to inspect and maintain large park areas. These trends reflect a growing awareness of the importance of preserving nature and creating comfortable and environmentally friendly living spaces.

In France, as in other countries with developed horticulture, scientific approaches are used when forming the assortment of garden centers, which allow ensuring the stability and decorativeness of plant compositions. France is a recognized leader in the field of horticulture and landscape design. Its rich traditions, favorable climate and high consumer demand have formed one of the largest and most developed markets for ornamental planting material in Europe. The French market offers a huge selection of ornamental plants, from classic varieties to exotic novelties. Roses, lavender, bougainvillea, as well as a variety of coniferous and deciduous trees and shrubs are especially popular.

French producers adhere to strict quality standards, which guarantees the health and durability of plants. Much attention is paid to the selection of new varieties with increased resistance to diseases and pests. The demand for ornamental plants in France has a pronounced seasonality. The greatest demand is observed in spring and autumn, when the main landscaping work is carried out. France has a well-developed infrastructure for growing, selling and delivering ornamental plants. There are numerous nurseries, garden centers, wholesale bases and online stores offering a wide range of products. There is growing interest in environmentally friendly methods of growing plants and the use of local varieties. Gardens created according to the principles of biodiversity are becoming popular [3, 6, 7, 8, 11, 12].

France, as one of the leading countries in the field of horticulture and landscape design, actively supports this sector through government programs. These programs are aimed at stimulating the development of horticulture, preserving biodiversity, supporting small and medium-sized enterprises and promoting environmentally friendly production. Plan de relance - a large-scale program for the recovery of the French economy after the COVID-19 pandemic, which involves significant investments in agriculture, including horticulture [3, 6,]. Plan Bio 2030 - a national program for the development of organic farming, which involves increasing the area under organic crops, including fruit and berry crops [3, 6,]. Plans de filières are sectoral plans for various agricultural sectors, including horticulture, which define strategic objectives and measures for the development of each sector [3, 6, 7, 8, 11, 12].

The French National Institute of Statistics and Economic Research (INSEE) indicates that the components of the floral sector are professional gardeners and landscape designers - 40%, this segment is one of the largest consumers of ornamental planting material who prefer high-quality plants that match their projects [5-9, 21-26].

Private gardeners make up 20%, they are amateurs looking for plants for their gardens, balconies and terraces [11, 12]. Municipalities and public institutions make up 55%, purchasing ornamental plants for landscaping parks, squares and other public spaces.

The French Ministry of Agriculture, according to the latest data, highlights that the area of licensed nurseries in 2023 is over 5 thousand hectares, but in 2001 their area was only 3 thousand hectares. Most of the ornamental nurseries are located in the Burgundy-Franche-Comté region. All of them are members of the Association of Florists and Gardeners of France.

Statistics on the sales of the garden market in France 2010-2023 show that the total turnover of the French horticultural sector increased to seven billion euros, but in 2021 it was only 6.84 billion euros, but by the end of 2024, garden center sales reached almost 7.3 billion euros.

The consumer price index for horticulture (flowers, plants, seeds, plants) in France 2020-2024 increased and reached 127.69. The distribution of garden center sales value in France in 2023 by category, established garden centers and seed companies accounted for more than a quarter of the total turnover of French garden centers in 2013. The division of the French flower market into three main segments – cut flowers, potted plants and planting material – is a fairly common practice in this industry. Each of these segments has its own characteristics, trends and challenges.

The cut flower market segment includes flowers that are grown for cutting and further sale in vases, bouquets and arrangements. As for the features, this is high competition among producers and suppliers, both local. The demand for certain types of cut flowers varies depending on the season and holidays, they have a limited shelf life, which requires quick sale and special transportation conditions, which affects their cost. Current trends include the demand for exotic species, the development of online sales and the demand for environmentally friendly flowers grown without the use of harmful chemicals. The cut flower market segment includes flowers that are grown for cutting and subsequent sale in vases, bouquets, and compositions. Regarding its features, there is high competition among local and other producers and suppliers. Demand for certain types of cut flowers varies depending on the season and holidays. They have a limited shelf life, requiring quick sale and special transportation conditions, which affects their cost. Current trends include demand for exotic varieties, the development of online sales, and demand for environmentally friendly flowers grown without the use of harmful chemicals.

The potted plant market segment includes plants that are grown in pots and are intended for cultivation in homes, offices, or outdoor areas. Features include a wide selection of plants with different shapes, sizes, and colors; growing potted plants takes more time compared to cut flowers, but potted plants have a higher value than cut flowers. Current trends show that plants with simple shapes and minimal care requirements are gaining popularity. There is a growing interest in plants for vertical interior landscaping and demand for plants that improve indoor air quality.

The planting material market segment includes seeds, bulbs, seedlings, and other materials necessary for plant propagation. Features include that the demand for planting material strongly depends on the season. Planting material allows consumers to grow plants themselves, which promotes the development of gardening. The development of landscape design and the increasing interest in gardening stimulate the demand for planting material. Trends include a growing demand for plants that can be used to create beautiful garden compositions.

Garden centres in Europe play an important role in landscape design, gardening and providing consumers with a variety of plants and related products. They have evolved from simple nurseries to comprehensive retail outlets offering a wide range of products and services. Here are the main aspects and characteristics of garden centres in Europe. Variety of formats and sizes. Large chain garden centres. In many European countries, there are large chains of garden centres that have several branches throughout the country or even in different countries. They offer a wide range of products and often have additional services such as cafes, playgrounds and advice centres. Examples include B&Q and Homebase in the UK, Hornbach and Obi in Germany and elsewhere. Independent family-run garden centres. Many garden centres remain independent family-run businesses, often with a narrower specialism or a specific approach to customer service. They may focus on local plants, organic gardening or rare species. Specialized nurseries: Some garden centers specialize in certain types of plants, such as roses, alpine plants, fruit trees or ornamental shrubs.

Product range and services. Plants The main range includes a wide selection of ornamental plants for the garden and home: annual and perennial flowers, ornamental shrubs and trees, conifers, houseplants, vegetable and fruit seedlings. Related products Garden centers offer everything you need for gardening: soil, fertilizers, plant protection products, pots, tools, garden furniture, garden decor, fountains, lighting, as well as products for pets. Many garden centers provide additional services such as landscape design, gardening advice, plant delivery, plant transplanting, gardening workshops and seminars.

The next step in Table 1. is advisable to consider the largest garden centers in France, which grow a wide assortment of annual and perennial flowers used for landscaping gardens, parks, and flowerbeds, and specialize in growing exotic plants that are in demand among collectors, and conduct gardening master classes.

Table 1. Characteristics of garden centers and nurseries in France

Name	**Area**	**Activities**
CasaNova	10 hectare.	nursery, individual landscaping project, rent the necessary garden tools
La Graineterie du Marché	8 hectare	garden center and nursery, seed and plant store, offering a wide range of seeds and plants, as well as advice on growing and caring for plants.
Le Prince Jardinier	8 hectare	garden center and nursery, has a botanical focus and offers no less than 1,300 specimens of trees, shrubs, conifers, old roses, bamboo and cereals, climbing plants, heather and perennials.
Truffaut	6 hectare	garden center and nursery, has a botanical focus and offers no less than 800 specimens of trees, shrubs, conifers, old roses, bamboo and grasses, climbing plants, heather and perennials.
Au Jardin d'Edgar	6 hectare	garden center and nursery, growing and selling one of the largest selections of unusual and hardy plants of excellent quality

Source: generated by the author

The range often changes depending on the season. For example, in spring, seedlings and flowers for planting predominate, in summer, garden furniture and decor, in autumn, bulbs and plants for autumn planting, and in winter, New Year's goods and Christmas decorations. Trends and features. Ecology and sustainable development there is a growing interest in environmentally friendly plants, organic fertilizers and plant protection products. Many garden centers promote products grown in compliance with environmental standards. The growth of popularity of indoor plants as in recent years there has been a significant increase in interest in indoor plants, which has led to an expansion of the range and the creation of special areas in garden centers. Online sales many garden centers are actively developing their online platforms for selling plants and related products, and also offer delivery services. Customer orientation garden centers strive to create a comfortable and attractive atmosphere for buyers, providing quality advice and a wide selection of products. Integration with the local community some garden centers cooperate with local farmers and producers, offering products of local origin. Educational events: Many garden centers hold workshops, lectures, and other educational gardening events to engage customers and raise their awareness.

The characteristics of garden centers and nurseries on the French Riviera include the creation of an extensive network of both private nurseries and those owned by municipalities [5, 9, 10], the use of the latest technologies for propagation and cultivation of planting material with unusual shapes, colors, and aromas, increased use of container cultivation [8, 9], and the cultivation of environmentally friendly plants without the use of harmful chemicals [5, 11].

It is advisable to consider innovative technologies used for growing cut flowers in garden centers in France. Hydroponics is actively applied, which involves growing plants without using soil, but in a nutrient solution, with the plant roots constantly in water enriched with necessary minerals. Aeroponics is an even more modern technology, where plant roots are suspended in the air, and nutrients are supplied in the form of a fine mist. The advantages of these methods are higher yields due to rapid growth and a large number of flowers that have brighter colors and last longer with less water usage than traditional cultivation, and the possibility of cultivation in any conditions.

The implementation of artificial LED lighting systems, which provide the optimal light spectrum for plant growth, allows for regulating the duration of day and night and stimulating flowering. Special lamps emit the light necessary for photosynthesis. The advantages are independence from natural light and energy savings.

Garden centers actively use climate control systems as automated systems ensure optimal temperature, humidity, and CO2 levels in greenhouses. Sensors constantly monitor growing conditions and transmit data to a computer for analysis and adjustment, creating ideal conditions for plant growth to obtain high-quality products, and optimal conditions hinder the development of diseases and pests.

France is known for the development of new varieties through genetic modification, i.e., creating new varieties with desired characteristics such as disease resistance, long shelf life, and bright colors. Traditional breeding contributes to the expansion of the assortment of new varieties with unusual shapes, colors, and aromas, which are more resistant to diseases and pests and have a longer shelf life. Other modern technologies include robotic systems for performing routine operations such as planting plants, harvesting, and packaging. Dosing fertilizer systems ensure precise fertilizer application, which allows for reducing costs and decreasing environmental pollution. Biological protection systems utilize beneficial insects and microorganisms to combat pests and diseases. The use of modern technologies allows for increasing the efficiency of flower production, improving their quality, and expanding the assortment. This, in turn, allows for meeting the growing consumer demand for fresh and beautiful flowers.

The French ornamental planting material market is dynamic and promising. It is characterized by high-quality standards, a diverse assortment, and a constant search for new solutions. Understanding the features of this market is important for producers, sellers, and all those interested in ornamental gardening. French flower nurseries are industry leaders due to their traditions, innovations, and high product quality. They play an important role in shaping global trends in floriculture and provide us with a variety and beauty of plants.

Foreign experience in horticulture planning demonstrates a variety of approaches that take into account both natural and climatic conditions, as well as economic and social needs.

Table 2. The following key trends are observed in countries with developed horticulture

The use of modern technologies:	The introduction of precision agriculture, including GPS navigation, remote sensing, automated irrigation and fertilizer application systems, allows you to optimize resource consumption and increase yields.
Breeding and introduction of new varieties:	Countries with developed horticulture are actively investing in scientific research and breeding new varieties of fruit and vegetable crops, characterized by high yields, resistance to diseases and pests, as well as improved consumer qualities.
Organization of production and logistics:	In many countries, great attention is paid to the organization of cooperatives and producer associations, which contributes to the consolidation of efforts, improving access to sales markets and optimizing logistics processes. European countries, such as Italy and Spain, have developed cooperative systems that ensure effective sales of products.
Sustainable gardening and environmental safety:	In many countries, there is a trend towards the implementation of sustainable gardening practices aimed at minimizing the negative impact on the environment. This includes the use of organic fertilizers, biological methods of pest control, as well as optimizing water consumption.
Production diversification and niche crops:	In many countries, farmers diversify their production, growing not only traditional crops, but also niche crops that are in high demand in local or export markets. This allows reducing risks and increasing profitability.
Government support and regulation:	In many developed countries, the government provides support to the horticultural industry through financial programs, advisory services, and regulatory mechanisms aimed at improving product quality and protecting the interests of producers.

France, as a country with rich floristic traditions, offers a wide range of cut flowers. The classification of this variety can be carried out according to various criteria: seasonality, color, shape, purpose and other characteristics.

The classification of ornamental plants is often based on the conditions of their cultivation. One of the main criteria is the place of cultivation. Thus, plants are divided into those that can grow and develop in open ground without additional shelter, and those that require protected conditions of greenhouses (closed ground). The latter are not able to survive in winter conditions of open ground. Since the horticultural enterprises of France include the cultivation of flowers of mixed conditions, it is advisable to consider the appropriate classification.

The next step is to consider the factors influencing the assortment of a garden company in Europe, which are a set of interrelated factors that determine which plants, goods and services will be offered to customers. These factors can be divided into several main categories.

1. Consumer demand and market trends. The demand for certain types of plants and related products varies significantly depending on the season. For example, in spring, demand increases for seedlings and flowers for planting, in summer - for garden furniture and lawn care products, in autumn - for bulbs and plants for autumn planting, in winter - for New Year's products and products for protecting plants from frost. Fashion trends in gardening and landscape design, such as changes in gardening styles, the popularity of certain types of plants (for example, succulents, herbs, roses of certain varieties), as well as trends in the design of garden plots, affect the assortment. The level of income of the population and the purchasing power, i.e. the economic situation in the region, affect the willingness of consumers to spend money on garden products. During periods of economic growth, the demand for more expensive and exclusive products may increase. The age, family composition, lifestyle of consumers affect their needs and preferences. For example, young families may be interested in easy-to-care plants for apartments and balconies, while older people may prefer

traditional garden crops. The demand for organic fertilizers, biological plant protection products and plants grown without the use of chemicals is growing.

2. Climatic and geographical conditions. Climatic conditions (temperature, rainfall, length of daylight hours) significantly affect the choice of plants that can be successfully grown and sold in a particular region of Europe. The characteristics of the soil in a particular region may limit the choice of plants that will grow well in local conditions. Certain local plant species or traditional garden crops may be popular in some regions.

3. Suppliers and logistics. The range depends on what plants are available from suppliers (nurseries, seed producers, importers). The cost and complexity of delivering plants can influence the choice of range, especially for exotic or sensitive species. Suppliers also have seasonality in the production and supply of plants.

4. Internal factors of the garden enterprise. Large chain garden centers can afford a wider range, while small specialized nurseries can focus on certain types of plants. The amount of investment in the purchase of goods, storage and marketing affects the breadth and depth of the range. The knowledge and experience of employees in the field of horticulture can affect the choice and quality of the range presented. Determining the target audience and positioning in the market affects the formation of the range. For example, the enterprise can focus on the elite segment or on the mass consumer. If the garden center offers landscape design services or consulting, this can affect the range of plants offered for sale.

5. Regulatory and legal aspects. The presence of certain quarantine restrictions or requirements for the quality of planting material may affect the choice of plant species that can be implemented. Legislative restrictions on the use of certain plant protection products or requirements for the environmental friendliness of products may affect the assortment. All these factors interact and influence each other, forming a complex decision-making process regarding the assortment of goods in European horticultural enterprises. A successful horticultural enterprise must carefully analyze these factors in order to offer its customers a relevant, sought-after and competitive assortment.

The problems of the ornamental plant market in Europe are multifaceted and include both economic and environmental, social and technological aspects. Here are the main ones:

1. Competition and pricing. High competition as the ornamental plant market is very competitive, both between local producers and with importers from other countries (in particular, from countries with lower production costs). This can lead to pressure on prices and reduced profitability for European producers. Price volatility prices for ornamental plants can fluctuate significantly depending on seasonality, weather conditions, holiday periods and other factors, which makes planning and forecasting difficult for companies.

2. Production challenges. High production costs, i.e. costs for labor, energy, fertilizers, plant protection products and other resources in Europe are relatively high, which affects the cost of production. Dependence on weather conditions as plant cultivation is dependent on climatic conditions, which can lead to crop losses due to adverse weather conditions (droughts, frosts, strong winds, etc.). The spread of diseases and pests can cause significant losses to producers, requiring additional costs to combat them. In some regions of Europe, there is a shortage of qualified workers for horticulture.

3. Environmental problems and sustainable development. Use of pesticides and environmental pollution as traditional cultivation methods may involve the use of chemical plant protection products, which can have a negative impact on the environment and the health of consumers. Water consumption: Plant cultivation requires significant amounts of water, which can be problematic in arid regions or with limited water resources. The problem of disposing of waste from the production and sale of plants (e.g. plastic pots) is relevant. Significant volumes of imports and exports of ornamental plants lead to increased greenhouse gas emissions.

4. Changes in consumer preferences. Growing demand for environmentally friendly products, i.e. consumers are increasingly interested in plants grown in compliance with environmental

standards and without the use of chemicals. Changing trends in landscape design require the adaptation of the assortment to new trends in garden and interior design. Growth of online trade: Competition from online platforms can put pressure on traditional sales channels.

5. Logistics and storage. Transporting live plants requires special conditions and can be difficult and expensive. Limited shelf life ornamental plants have a limited shelf life, which requires fast sales and efficient logistics.

6. Regulatory regulation. Strict phytosanitary requirements and border controls can complicate the import and export of plants. Compliance with European environmental standards may require additional costs for producers.

7. Seasonality and dependence on holidays. The demand for ornamental plants is highly dependent on the season and holiday periods, which can lead to uneven utilization of production capacities and difficulties in planning.

8. Innovation and technology. The introduction of new cultivation technologies (e.g. hydroponics, aeroponics), automation and production management may require significant investments.

Solving these problems requires an integrated approach at the level of both individual enterprises and industry organizations and government authorities. This includes the introduction of environmentally friendly production methods, investments in innovation, optimization of logistics, adaptation to changing consumer preferences and support for the sustainable development of the industry.Table 3. with the production classification of cut flowers for Europe, which may include the main categories and some examples. It is worth noting that the classification may vary depending on the source and the purpose of the classification (e.g. for statistics, trade, scientific research). This table provides a general overview.

The European cut flower market is constantly changing, responding to current trends and consumer needs. Here are some of the main European trends and popular types of flowers. Roses remain classics and are still popular. A variety of colors and varieties allows you to create a variety of bouquets. Tulips are especially popular in spring, symbolizing freshness and renewal. A variety of colors and shapes make them universal for various compositions. Chrysanthemums are distinguished by their durability and variety of shapes. They are used both in monobouquets and in complex compositions. Lilies are exquisite and fragrant flowers that add elegance to any bouquet. Popular both in monobouquets and in combination with other flowers. Gerberas are bright and cheerful flowers that lift the mood. They are used to create cheerful bouquets. Alstroemerias are distinguished by their long-lasting freshness. Popular in assembled bouquets. Eustoma (lisianthus) has delicate, elegant flowers that resemble roses. Popular in wedding bouquets and romantic arrangements. These trends and types of flowers reflect the modern tastes and needs of European consumers, as well as the desire for sustainability and innovation in the floral industry.Let's consider step by step the characteristics and features of flowers grown by French garden enterprises. The entire species composition is represented by about 700 species, which are both sold and grown. But accordingly, the study will focus only on the main flowers of open ground, namely Sunflower *(Helianthus annuus),* Lavender (*Lavandula L.*), Peonies (*Paeonia L.*), Dahlias (Dahlia) and (*Antirrhinum majus*)

Dahlias a genus of about 40 species of flowering plants from the Asteraceae family, common in the high altitudes of Mexico and Central America. Approximately six species of the Dahlia genus have been bred for cultivation as ornamental flowers and are popular in the flower industry and gardens. Thousands of varieties of dahlias are classified into different types, including single, double, pompon, cactus, water lilies, peonies and table dahlias.

Table 3. Production classification of cut flowers for Europe

Category	**(Main Group) Subcategory**	**(Examples) Characteristics**	**Examples of Flowers**
Roses	Hybrid Tea	Most popular, large flowers on long stems, various colors.	*Red Naomi, Freedom, Explorer, Black Baccara*
	Spray Roses	Several flowers on one stem, smaller in size, often used in bouquets.	*Sweet Avalanche Spray, Pink Spray, Yellow Spray*
	Bush Roses	Flowers on shorter stems, often used for arrangements and decoration.	*(Various varieties, depending on the species)*
Chrysanthemums	(Single-headed)	various shapes and colors.	*Anastasia, Zembla, Baltica*
	Spray Chrysanthemums	Many smaller flowers on one stem, create voluminous compositions.	*Zembla Spray, Anastasia Spray, Spider Chrysanthemums*
Tulips	Single Early	Single goblet-shaped flowers, early flowering.	*Couleur Cardinal, White Prince*
	Double Early	Double flowers, early flowering.	*Monte Carlo, Abba*
	Triumph Most common,	various shapes and colors.	*Ile de France, Strong Gold*
	Darwin Hybrids	Large flowers on strong stems.	*Apeldoorn, Oxford*
Peony-flowered	Double flowers,	similar to peonies.	*Double Touch, Columbus*
	Lilies Asiatic	Various colors, often odorless, early flowering.	*Tiny Tim, Elodie*
	Oriental	Large flowers with strong aroma, later flowering.	*Casa Blanca, Stargazer*
	Trumpet	Large tubular flowers, strong aroma.	*Regale Lily, Golden Splendor*
Carnations (Carnations)	Standard Large	single flowers on a stem, various colors.	*White Liberty, Red Berlin*
	Spray Carnations	Many smaller flowers on one stem.	*Pink Spray, Yellow Spray*
Alstroemeria	Various colors and shapes of flowers, long shelf life.	Often used in bouquets and arrangements.	*Princess Lily, Inca Ice*
Gerbera	Large bright flowers, various colors and shapes.	Popular as single flowers and in bouquets.	*Festival, Spider Gerbera*
Irises	Various types and colors, elegant flowers	Often used in spring arrangements.	*Dutch Iris, Bearded Iris (if cut)*
Exotic flowers Orchids, Strelitzia, Protea and others.	Flowers with an unusual appearance,	often used in special arrangements.	*Phalaenopsis (as cut), Bird of Paradise, King Protea*

Dahlias are tuberous perennials, and most have simple leaves that are segmented and toothed or dissected. The compound flowers can be white, yellow, red, or purple. Wild dahlias have both disc and ray flowers in their flower heads, but many ornamental varieties, such as the common garden dahlia (D. bipinnata), have shortened ray flowers. Dahlias grow well in most garden soils. They begin flowering in late summer and continue flowering until frost breaks in the fall.

Biological classification:
Kingdom: Plantae
Division: Streptophyta
Superclass: Angiosperms (Magnoliophyta)
Class: Dicotyledoneae
Subclass: Asteridae
Order: Asterales
Family: Asteraceae
Genus: Dahlia

Fig. 1. *Dahlia*

Lavandula L. belongs to the family Lamiaceae, subfamily Lavanduloideae Briq., and includes about 30 species distributed from Macaronesia and the Mediterranean basin to India [1]. Lavandula is a strictly Mediterranean genus, with individual members found in the Arabian Peninsula, Socotra, Somalia and India.

Biological classification:
Kingdom: Plantae
Division: Angiosperms
Class: Eudicots
Subclass: Asteridae
Order: Labiatae
Family: Labiatae
Genus: Lavender
Species: Lavandula angustifolia (medicinal)

Fig 2. *Lavandula L*

This is an evergreen subshrub from 30 to 60 centimeters high. A characteristic feature of the plant is the high content of essential oil, especially in fresh inflorescences (0.8-1.6%). The leaves contain a slightly smaller amount of oil (0.3%). The main components of the essential oil are linalool esters (in particular, acetic, butyric, valeric and caproic), as well as other compounds such as geraniol, citral, borneol and amyl alcohol. The root system of lavender is represented by a woody root, which is significantly thickened in the upper part and densely covered with small roots. The root system penetrates deep into the soil, providing the plant with moisture and nutrients. The shoots of lavender are semi-woody, forming a spherical bush. The average lavender bush has about 400-500 such shoots.

The leaves are opposite, that is, arranged in pairs on the stem. They are sessile, that is, they do not have petioles, and fit tightly to the stem. The color of the leaves varies from dark green to light green, often with a grayish tint. The shape of the leaves is linear or lanceolate, narrowed at both ends. The edges of the leaves are slightly curved downwards. Lavender leaves are evergreen, that is, they remain on the plant throughout the year.

Peonies (Paeonia L.) are a genus of perennial herbaceous and shrubby plants of the Paeoniaceae family. These plants are known for their beauty and long flowering, which makes them one of the most beloved ornamental plants in gardens. Peonies (Paeonia L.) are a genus of perennial herbaceous and shrubby plants, which includes about 40 species.

Biological classification:
Kingdom: Plantae
Division: Tracheophyta
Class: Angiosperms
Clade: Eudicots
Subclass: Saxifragales
Family: Paeoniaceae
Raf.
Genus: Paeoni

Fig. 3. *Paeonia L.*

They are distinguished by a powerful root system, large pinnately dissected or palmately dissected leaves and large, bright single or collected in brush-shaped inflorescences flowers. The fruit of the peony is a many-leaved fruit. Herbaceous peonies annually shed the above-ground part, and tree-like ones have woody stems that do not die off for the winter. ITO hybrids combine the features of both groups, distinguished by large flowers of various colors.

Peonies are light-loving, prefer fertile, well-drained soils. They are valuable ornamental plants that are used for single plantings, creating flower arrangements and decorating gardens and parks.

Common sunflower (Helianthus annuus) or annual sunflower is a species of herbaceous plant that belongs to the Asteraceae family. Sunflower (Helianthus annuus) is an annual herbaceous plant of the Asteraceae family, distinguished by its powerful stem, large leaves and bright inflorescences-baskets. The stem of the sunflower is erect, branched in the upper part, reaches a height of 0.6 to 3 meters. It is covered with stiff hairs, which give the plant a rough appearance. The leaves are arranged alternately on the stem, have long petioles. The leaf blade is large, oval-cordate in shape, with a serrated edge. The upper surface of the leaf is rough, covered with short stiff hairs. The inflorescence is a basket, 30-50 cm in diameter. The marginal flowers are reedy, bright yellow, infertile. The central flowers are tubular, smaller, brownish-yellow, bisexual. An interesting feature of the sunflower is heliotropism - the ability of young inflorescences to turn after the sun during the day. The fruit is an achene that contains oil. The achenes have a variety of colors: from white to black, often with a characteristic striped pattern. Distribution and use: The common sunflower originates from North America, where it was cultivated by the Indians. It was brought to Europe by the Spanish conquistadors in the 16th century. Now the sunflower is widely cultivated as an oil crop around the world, including in Ukraine.

Biological classification:
Kingdom: Plantae
Division: Angiosperms
Class: Dicotyledons
Order: Asteraceae
Family: Asteraceae
Genus: Sunflower
Species: Sunflower

Fig. 4. *Helianthus annuus*

Antirrhinum majus is a flowering plant that belongs to the plantain family (Latin Plantaginaceae)

Biological classification:
Domain: Eukaryota
Kingdom: Plantae
Division: Streptophyta
— Vascular plants (Tracheophyta)
— Angiosperms (Magnoliophyta)
— Eudicots
Subclass: Asteridae
Order: Lamiales
Family: Plantaginaceae
Tribe: Antirrhineae
Genus: Antirrhinum
Species: Antirrhinum

Fig. 5. *Antirrhinum majus*

Antirrhinum majus is a bright representative of the family, originating from the warm regions of the Mediterranean, Asia and America. The unusual shape of the flower, resembling an open mouth, has earned the plant the popular name "dog". Although according to the biological classification, garden mouth is a perennial, in culture it is grown as an annual. The color of the flowers is extremely diverse: from white and yellow to rich burgundy and almost black. The only shades that are absent from the mouth palette are blue and blue. Garden mouth propagates by seeds. The optimal time for sowing seedlings is February-March. The seeds are distributed over the surface of a moist substrate, lightly sprinkled with a thin layer of soil, after which the container is covered with glass or film to maintain high humidity. At a temperature of 20-22 °C, shoots appear within 10-14 days. For successful seed germination, it is important to ensure constant soil moisture. The grown seedlings are planted in open ground in the second half of May, maintaining a distance of 20-30 cm between plants. The optimum temperature for plant growth and development is 10-18 °C.

The flowering of garden marigold is long, begins in June and can continue until October. The life span of an individual flower reaches 12 days. Regular removal of faded inflorescences stimulates the formation of new buds and extends the flowering period.

Garden marigold is a universal plant for decorating flower arrangements. It is used to create flower beds, mixborders, group and mass plantings to form flower carpets, container compositions for decorating balconies, terraces and loggias.

In addition, garden marigold is a popular crop for cutting. Cut flowers stay fresh in a vase for a long time (7-14 days), which allows them to be used to create bouquets and floral arrangements.

Garden marigold is an unpretentious and grateful plant that will become a bright decoration of any garden. Due to the variety of varieties in color and long flowering period, garden marigold is an indispensable element in the design of flower beds.

Foreign experience in horticulture planning demonstrates the importance of an integrated approach, including the introduction of modern technologies, the selection of new varieties, the optimization of production and logistics processes, as well as the consideration of environmental aspects. Adaptation and implementation of best practices, taking into account the specific conditions of Ukraine, can significantly increase the efficiency and competitiveness of domestic horticulture, contributing to the provision of the population with quality products and the development of the industry's economy.

REFERENCES

1. Debray, K., Le Paslier, M.C., Bérard, A., Thouroude, T., Michel, G., Marie-Magdelaine, J., Bruneau, A., Foucher, F., and Malécot, V. (2021). Unveiling the patterns of reticulated evolutionary processes with phylogenomics: hybridization and polyploidy in the genus Rosa. *Systematic Biology* . https://doi.org/10.1093/sysbio/ syab064
2. Hibrand-Saint Oyant, L., Roccia, A., Cavel, E., Caissard, J.-C., Machenaud, J., Thouroude, T., Jeauffre, J., Bony, A., Dubois, A., Vergne, P., et al. (2019). Biosynthesis of 2-phenylethanol in rose petals is linked to the expression of one allele of RhPAAS. *Plant Physiology* 179 (3), 1064–1079. https://doi.org/10.1104/ pp.18.01468
3. Hibrand Saint-Oyant, L., Ruttink, T., Hamama, L., Kirov, I., Lakhwani, D., Zhou, N.N., Bourke, P.M., Daccord, N., Leus, L., Schulz, D., et al. (2018). *A high-quality genome sequence of Rosa chinensis to elucidate ornamental traits. Nature Plants* 4, 473–484. https:// doi.org/10.1038/s41477-018-0166-1
4. Iwata, H., Gaston, A., Remay, A., Thouroude, T., Jeauffre, J., Kawamura, K., Hibrand-Saint Oyant, L., Araki, T., and Denoyes, B. (2012). The TFL1 homologue KSN is a regulator of continuous flowering in rose and strawberry. *The Plant Journal* 69, 116–125.
5. Joyaux, F. (2001). La Rose, une Passion Française, Histoire de la Rose en France 1778-1914 (Bruxelles: Editions Complexe).
6. Joyaux, F. (2005). Les Roses de l'Impératrice. La Rosomanie Française au Temps de Joséphine (Paris: Editions Complexe). Kawamura, K., Hibrand-Saint Oyant, L., Crespel, L., Thouroude, T., Lalanne, D., and Foucher, F. (2011). Quantitative trait loci for flowering time and inflorescence architecture in rose. TAG *Theoretical and Applied Genetics* 122 (4), 661–675.
7. Kawamura, K., Hibrand-Saint Oyant, L., Thouroude, T., Jeauffre, J., and Foucher, F. (2015). Inheritance of garden rose architecture and its association with flowering behaviour. Tree Genetics & Genomes 11 (2), 22. https://doi.org/10.1007/s11295-015- 0844-3
8. Labbé, J. (2014). LOI n° 2014-110 du 6 février 2014 visant à mieux encadrer l'utilisation des produits phytosanitaires sur le territoire national.
9. Leus, L., Van Laere, K., De Riek, J., and Van Huylenbroeck, J. (2018). Rose. In Ornamental Crops, Vol 11, J. Van Huylenbroeck, ed. (Cham: Springer International Publishing), p.719–767.
10. Li-Marchetti, C., Le Bras, C., Chastellier, A., Relion, D., Morel, P., Sakr, S., Crespel, L., and Hibrand-Saint Oyant, L. (2017). 3D phenotyping and QTL analysis of a complex character: rose bush architecture. *Tree Genetics & Genomes* 13 (5), 112. https://doi. org/10.1007/s11295-017-1194-0

11. Liorzou, M., Pernet, A., Li, S.B., Chastellier, A., Thouroude, T., Michel, G., Malecot, V., Gaillard, S., Briee, C., Foucher, F., et al. (2016). Nineteenth century French rose (Rosa sp.) germplasm shows a shift over time from a European to an Asian genetic background. *Journal of Experimental Botany* 67 (15), 4711–4725. https://doi.org/10.1093/jxb/ erw269
12. Lopez Arias, D., Chastellier, A., Thouroude, T., Bradeen, J., Van Eck, L., De Oliveira, Y., Paillard, S., Foucher, F., Hibrand-Saint Oyant, L., and Soufflet-Freslon, V. (2020). Characterization of black spot resistance in diploid roses with QTL detection, meta-analysis and candidate-gene identification. TAG *Theoretical and Applied Genetics* 133 (12), 3299–3321. https://doi.org/10.1007/s00122- 020-03670-5
13. Magnard, J.L., Roccia, A., Caissard, J.C., Vergne, P., Sun, P.L., Hecquet, R., Dubois, A., Hibrand-Saint Oyant, L., Jullien, F., Nicole, F., et al. (2015). *Biosynthesis of monoterpene scent compounds in roses. Science* 349 (6243), 81–83. https://doi.org/10.1126/ science.aab0696
14. Marolleau, B., Petiteau, A., Bellanger, M.B., Sannier, M., Le Pocreau, N., Porcher, L., Paillard, S., Foucher, F., Thouroude, T., Serres-Giardi, L., et al. (2020). Strong differentiation within Diplocarpon rosae strains based on microsatellite markers and greenhouse-based inoculation protocol on Rosa. Plant Pathology 69, 1093–1107, https://doi.org/10.1111/ppa.13182
15. Proïa, F., Panloup, F., Trabelsi, C., and Clotault, J. (2019). Probabilistic reconstruction of genealogies for polyploid plant species. *Journal of Theoretical Biology* 462, 537–551.
16. Randoux, M., Davière, J.M., Jeauffre, J., Thouroude, T., Pierre, S., Toualbia, Y., Perrotte, J., Reynoird, J.P., Jammes, M.J., Hibrand-Saint Oyant, L., and Foucher, F. (2014). RoKSN, a floral repressor, forms protein complexes with RoFD and RoFT to regulate vegetative and reproductive development in rose. *New Phytologist* 202 (1), 161–173.
17. Redouté, P.-J., and Thory, C.-A. (1817-1824). Les Roses, 3 vols. (Paris: Firmin-Didot). Roberts, A., Debener, T., and Gudin, S. (2003). Encyclopedia of Rose Science (Oxford: Elsevier, Academic Press). eBook ISBN: 9780080917979.
18. Roman, H., Rapicault, M., Miclot, A.S., Larenaudie, M., Kawamura, K., Thouroude, T., Chastellier, A., Lemarquand, A., Dupuis, F., Foucher, F., et al. (2015). Genetic analysis of the flowering date and number of petals in rose. *Tree Genetics & Genomes* 11 (4). https://doi.org/10.1007/s11295-015-0906-6
19. Roux-Cuvelier, M., Grisoni, M., Bellec, A., Bloquel, E., Charron, C., Delalande, M., Delmas, M., Didier, A., Durel, C.-E., Duval, C.-H., et al. (2021). Conservation of horticultural genetic resources in France. *Chronica Hortic*. 61 (2), 21–36.
20. Simon, L., and Cochet, P. (1906). Nomenclature de Tous les Noms de Roses, 2nd edn (Librairie Horticole).
21. Soufflet-Freslon, V., Araou, E., Jeauffre, J., Thouroude, T., Chastellier, A., Michel, G., Mikanagi, Y., Kawamura, K., Banfield, M., Oghina-Pavie, C., et al. (2021). Diversity and selection of the continuous-flowering gene, RoKSN, in rose. *Horticulture Research* 8, 76, https://doi.org/10.1038/ s41438-021-00512-3
22. Robinson N. The Planting Design Handbook Burlington. Ashgate publishing company, 2004. S. 420.
23. Gregorio, N.; Herbohn, J.; Harrison, S.; Smith, C. A systems approach to improving the quality of tree seedlings for agroforestry, tree farming and reforestation in the Philippines. *Land Use Policy*. 2015, 47, 29– 41. URL: https:// doi.org/10.1007/s11842-016-9344-z.
24. Haase, Diane & Davis, Anthony. Developing and supporting quality nursery facilities and staff are necessary to meet global forest and landscape restoration needs. Reforesta. 2017, 4, 69–93. 10.21750/REFOR.4.06.45. *Notes in Current Biology,* 1 (1) 2021
25. Laestadius, L.; Buckingham, K.; Maginnis, S.; Saint-Laurent, C. Before Bonn and beyond: the history and future of forest landscape restoration. *Unasylva.* 2015, 245, 66(3), 11–18.
26. Oliet, J. A.; Jacobs, D. F. Restoring forests: advances in techniques and theory.New Forest. 2012, 43(5–6), 535–541. URL: https://doi.org/10.1007/ s11056-012-9354-4.
27. Sabogal, C.; Besacier, C.; McGuire, D. Forest and landscape restoration: concepts, approaches and challenges for implementation. Unasylva. 2015, 245, 66(3), 3–10.
28. Stanturf, J. A.; Palik, B. J.; Dumroese, R. K. Contemporary forest restoration: a review emphasizing function. For Ecol Manage. 2014, 331, 292–323.
29. Williams, J. Exploring the onset of high-impact mega-fires through a forest land management prism. *Forest Ecology and Management*. 2013, 294, 4–10. URL: https://doi.org/10.1016/ j.foreco.2012.06.030.

GREEN SPACES IN THE FOCUS OF STRATEGIC ENVIRONMENTAL ASSESSMENT: CHALLENGES AND PRACTICES OF UKRAINIAN COMMUNITIES

Yaroshchuk Svitlana
Ph.D. in Agricultural Sciences, Assistant Professor, Sumy National Agrarian University, Ukraine
ORCID ID: 0000-0001-6125-1979

Yaroshchuk Roman
Ph.D. in Agricultural Sciences, Assistant Professor, Sumy National Agrarian University, Ukraine
ORCID ID: 0000-0003-2591-5592

Introduction.

In the context of transformational changes taking place in Ukraine in the social, economic, spatial and environmental spheres, the implementation of strategic environmental assessment (SEA) at the level of territorial communities is of particular relevance. The SEA is an important tool for integrating the environmental component into strategic planning processes, which ensures a balance between socio-economic development and environmental protection.

For communities that develop and implement their development strategies, strategic environmental assessment allows not only to identify potential risks to the environment and public health, but also to ensure the formation of effective environmental policy at the local level. It serves as a basis for making informed management decisions that take into account long-term environmental, social and spatial impacts.

The SEA plays a special role in the preservation of green spaces, which are a key component of the urban and rural landscape. Green areas perform important ecosystem functions, such as air purification, microclimate regulation, noise reduction, and creating a comfortable environment for residents. In the context of expanding development and transport infrastructure, it is the SEA that allows us to assess in advance the risks of fragmentation or loss of green areas, propose alternative approaches to spatial planning, and establish protective regimes.

SEA is especially important in the context of post-war recovery, when communities are forced to combine the need for rapid economic growth with the obligation to restore and protect the natural environment. Thus, SEA is not only a legal requirement under the Law of Ukraine “On Strategic Environmental Assessment” but also a practical tool for implementing the principles of sustainable development declared in national and international policy.

The purpose of the study is to analyze the methodological basis for conducting strategic environmental assessment of community development strategies, assess the practical experience of its implementation in Ukraine, identify existing difficulties and outline possible areas for improving the process, taking into account current challenges and trends. One of the practical tools for implementing a transparent and high-quality strategic environmental assessment is the Unified Register of Strategic Environmental Assessment maintained by the Ministry of Environmental Protection and Natural Resources of Ukraine (available at https://eia.menr.gov.ua/seo).

The registry provides open access to the full package of SEA-related documents, including scoping statements, SEA reports, announcements of public discussions, conclusions of the authorized body and decisions on approval of documents. For local governments, this resource is a valuable source of examples and templates that can be used to prepare their own documents.

In addition, the registry allows the public to track the SEA process in any community in Ukraine, which increases the level of trust and involvement of residents in environmental management processes. For professionals, it is a convenient tool for monitoring the implementation of legislation, as well as a source for analytics and comparison between communities.

The use of the Unified SEA Registry is an important step towards the digitalization of strategic environmental planning, transparency of decision-making, and improvement of environmental governance in communities.

Regulatory and legal framework for SEA in Ukraine. The implementation of strategic environmental assessment in Ukraine is based on the adaptation of the principles and procedures enshrined in European legislation, in particular Directive 2001/42/EC of the European Parliament and of the Council of 27 June 2001 on the assessment of the effects of certain plans and programmes on the environment (SEA Directive). This legal act became the basic document for the development of Ukraine's national legislation in the field of strategic environmental planning.

Ukraine has committed to implement the provisions of Directive 2001/42/EC in accordance with the EU-Ukraine Association Agreement, in particular Annex XXX to Title V, Environment. As a result, in 2018, the Law of Ukraine 'On Strategic Environmental Assessment' No. 2354-VIII was adopted, which entered into force on 20 March 2018. This law establishes the legal and organisational framework for SEA and defines the procedure for conducting it for state planning documents (SPD) that may have a significant impact on the environment.

The SEA procedure in Ukraine is structured and includes the following steps:

- Preparation of a notification on the publication of the SPD and submission of an application for scoping the SEA;
- development of the SEA Report containing an analysis of the environmental status, vulnerability of the territories, predicted impacts, and alternatives;
- public discussion and obtaining a conclusion from the authorised body (Ministry of Environmental Protection and Natural Resources of Ukraine);
- taking into account the results of the assessment when approving the SPD;
- informing about the approval of the document with due regard to the SEA.

To ensure a uniform approach to the implementation of SEA in practice, the Ministry of Environmental Protection and Natural Resources has developed and approved the Methodological Recommendations for the Implementation of SEA of State Planning Documents (2021), as well as separate recommendations for urban planning documentation (2023). In 2024, Order No. 1382 of the Ministry of Environmental Protection and Natural Resources of Ukraine dated 31.10.2024 approved methodological recommendations for taking into account the climate component in state planning documents and during the implementation of strategic environmental assessment and environmental impact assessment. The guidelines clearly outline the sequence of actions, the content of the report, the requirements for impact assessment, and the specifics of taking into account public opinion.

In addition to Directive 2001/42/EC, the European SEA model also includes the implementation of the provisions of the Protocol on Strategic Environmental Assessment to the Espoo Convention. The Protocol provides for the procedure of environmental impact assessment in planning at the national and transboundary level.

Strategic environmental assessment is closely linked to the implementation of other environmental and urban planning laws of Ukraine, including:

- Law of Ukraine 'On Environmental Protection' https://zakon.rada.gov.ua/laws/show/1264-12#Text;
- The Law of Ukraine 'On Land Protection' https://zakon.rada.gov.ua/laws/show/962-15#Text;
- The Law of Ukraine 'On the Nature Reserve Fund of Ukraine' https://zakon.rada.gov.ua/laws/show/2456-12#Text;
- The Law of Ukraine 'On Regulation of Urban Development' https://zakon.rada.gov.ua/laws/show/3038-17#Text.

In this context, the European Green Deal, which was adopted by the European Commission in December 2019, is also an important benchmark for Ukraine's environmental policy. This strategy envisages achieving climate neutrality in the EU by 2050 and contains a number of initiatives aimed at protecting biodiversity, preserving ecosystems, reducing pollution, developing a circular economy and sustainable agricultural policy. As part of the Association Agreement, Ukraine has declared its readiness to gradually implement the approaches laid down in the Green Deal, which directly affects the strategic environmental assessment. In particular, the SEA is seen as a tool for integrating climate goals, biodiversity conservation and resource efficiency into strategic planning processes. This approach is in line with the pan-European trend of transforming spatial development on the basis of climate and environmental responsibility.

Thus, Ukrainian SEA legislation is the result of adaptation to European norms, which allows for unified approaches to integrating environmental considerations into planning processes. In practice, this means that all new community development strategies should not only contain economic and social goals, but also take into account long-term environmental impacts and ways to mitigate them in accordance with EU requirements.

Methodology of strategic environmental assessment. The methodology of strategic environmental assessment (SEA) in Ukraine is based on a systematic analysis of the environmental aspects of state planning documents (SPD), primarily community development strategies. This process involves identifying the potential impact of the implementation of strategies on the environment, public health, nature reserve objects, as well as the spatial structure of the territory, including green areas and plantations.

The SEA is conducted at the stage of development or approval of the SPD and aims to:

- identify environmental risks associated with the implementation of the strategy;
- assess the current state of the environment and vulnerable areas that may be adversely affected;
- to propose reasonable alternatives taking into account the principles of sustainable development;
- identify measures to mitigate or prevent negative impacts;
- ensure transparency of the process through public discussion.

An important component of the SEA is the consideration of ecosystem services, including the role of green spaces in improving air quality, reducing noise pollution, retaining moisture, and creating a comfortable microclimate. Public discussions are increasingly focusing on the reduction of green areas in the process of urbanisation, which increases the relevance of taking such aspects into account in strategic planning.

The SEA methodology requires mandatory analysis:

- the state of atmospheric air;
- quality of surface and groundwater;
- land use and soil structure;
- biodiversity;
- public health.

In the process of analysis, it is important to take into account cumulative and secondary effects, such as reduced accessibility of green areas as a result of the expansion of transport or housing infrastructure. Practice shows that it is through the SEA that it is possible to preserve certain areas of green spaces that have not been designated as nature reserve sites but have local ecosystem or social significance.

Another methodological feature is information on sensitive areas, taking into account the density of development, the presence of water bodies, green areas and recreational facilities. This information allows us to assess which projects or programmes may have a critical impact on the ecological balance.

It is important that the SEA is not a one-off procedure - its results should be integrated into further stages of the strategy implementation, accompanied by environmental monitoring and adjustments in case of changes in external conditions.

Thus, the SEA methodology in Ukraine includes tools that allow for early detection of threats to the reduction of green spaces and suggesting alternatives for their preservation and development, which is key to ensuring the environmental sustainability of communities.

Research results.

Strategic environmental assessment (SEA) has gradually become a mandatory and effective environmental monitoring tool for communities planning their development in accordance with the principles of sustainability. In 2024-2025, strategic environmental assessment reports were prepared on community development strategies in Poltava Oblast. In particular, for the Martynivska Rural Territorial Community, Velikobahachanska Settlement Territorial Community, Velykobudyshchanska Rural Territorial Community, Velykorublivska Rural Territorial Community, and Kolomatska Rural Territorial Community.

A standardised approach was applied to analyse the current state of the environment and the impact of the planned activities, in accordance with the Law of Ukraine 'On Strategic Environmental Assessment'. The main elements of these studies were studying the state of the air, water and land resources, biodiversity, and public health. Common to all communities was the need to assess the risks caused by the hostilities, including soil contamination, damage to infrastructure and increased social vulnerability.

In the process of strategic planning for the development of territorial communities, an important component is to take into account the opinions of residents, especially on issues related to the environmental state of the territory. Conducting surveys allows us to form a realistic picture of environmental problems, expectations and priorities of local residents. An analysis of the development strategies and strategic environmental assessment (SEA) reports of five communities in Poltava Oblast shows that this practice is becoming increasingly common.

In preparing the SEA report, it is worth noting that all five communities conducted a survey of residents in the process of drafting their development strategies. This indicates a high level of public involvement in the planning process. It is worth noting that the level of detail of environmental issues in the surveys depends on the specifics of the community and the form of research organisation.

The surveys included blocks related to environmental issues, including: the condition of green areas, the quality of drinking water, the need to clean water bodies, the problem of unauthorised landfills, the request for the expansion of recreational spaces, and expectations for greening settlements. In some cases, residents also spoke about the environmental impact of the hostilities, the need to control industrial waste and preserve forest resources.

The form of the survey varies. For example, in the Velykobahachanska community, it was organised in the form of an online survey, while in the Velykorubliivska and Martynivska communities it was conducted in the format of focus groups, open discussions or collection of written proposals during public hearings. This allowed us to reach both the general population and representatives of target groups (business, education, healthcare, and youth).

The results of the surveys were taken into account when formulating the strategic and operational goals of the development strategies. In particular, the environmental expectations of residents became the basis for setting priorities in the areas of environmental safety, development of environmental infrastructure, conservation of water resources, protection of green spaces, improvement of drinking water quality, etc.

An analysis of the results of a survey of residents of five territorial communities in Poltava Oblast shows clearly defined expectations for improving the environment, particularly in the areas of household waste, water supply, recreational space and the preservation of natural vegetation.

One of the requests of citizens was the need to preserve and restore forest belts. This aspect was directly or indirectly mentioned in the responses of residents of Martynivska, Velykorublivska and Kolomatska communities.

Forest belts perform an extremely important ecosystem function, protecting areas from wind erosion, improving the microclimate, reducing noise and dust, and creating biodiversity. In the context of climate change and intensification of agricultural production, their preservation is critical for sustainable development.

Water and air pollution, poor condition of green spaces, low level of environmental culture in households, inefficient waste collection and disposal systems, and poor maintenance of public spaces are also among the most common environmental problems identified by community residents. In some communities there is a growing interest in restoring the recreational potential of the area and protecting wetlands (Table 1).

Table 1. Results of a survey of community residents for planning development strategies

Community	Environmental issues in the survey	Main environmental issues according to the survey results
Velikobahachanska	Assessment of green areas, demand for clean water, recreational spaces	Pollution of water bodies, lack of landscaped green areas
Velykobudyshchanska	Water quality, air quality, household waste	Poor air quality, accumulation of household waste
Velykorublivska	Expectations for improved landscaping and waste management	Lack of garbage containers, unauthorized landfills
Kolomatska	The state of landfills, the need to clean up the river	Littered areas, the need to clean up the river
Martynivska	Environmental infrastructure, water quality, forest conservation	Problems with water supply, deforestation, illegal dumping

This data suggests that citizens' environmental awareness is growing, and the demand for systematic environmental planning is relevant. In particular, the restoration of protective forest belts can be included as a separate project or task in community strategy implementation plans. This will provide not only environmental but also social benefits, such as improved living conditions, health, and the development of local ecotourism.

Thus, the practice of interviewing residents not only creates a basis for the development of sound environmental policy, but also strengthens the dialogue between the authorities and citizens. This helps to improve the quality of strategic planning and adapt environmental measures to the real needs of the population.

It is worth noting that in each of the SEA projects, special attention was paid to green areas and their preservation.

The reports of the strategic environmental assessments have shown that biodiversity issues are beginning to take a prominent place in the strategic planning of communities. Although most of the threats are of anthropogenic origin - intensive agriculture, development, deforestation - some communities are already including preventive or compensatory measures in their strategies (Table 2).

In particular, the Velykobahachanska and Velykobudyshchanska communities are focused on the development of ecotourism and recreation as a tool for preserving landscape diversity. The Velykorublyvska community focused on waste management, which is an important factor in reducing environmental pressure on the natural environment. The Kolomatska community has highlighted the protection of coastal zones, while the Martynivska community focuses on ecosystem restoration.

Table 2. Risks to green spaces and corresponding measures provided for in community strategies

Community	Possible risks to green spaces	Measures to preserve/restore green spaces
Velikobahachanska	Habitat fragmentation, intensive agricultural use	Development of ecotourism, creation of new green areas
Velykobudyshchanska	Decrease in the number of species, degradation of natural ecosystems	Creation of recreational spaces, educational events on environmental issues
Velykorublivska	Pollution of territories, disturbance of natural habitats due to infrastructure projects	Environmental education, centralized and separate waste collection, creation of parks and recreation areas
Kolomatska	Deforestation, drainage of coastal areas	Protection of coastal strips, landscaping, wetlands protection
Martynivska	Disruption of ecosystems as a result of the war, reduction of natural habitats	Restoring ecosystems, preserving green areas, supporting local recreational infrastructure

Practice has shown that communities have begun to include the environmental component in all strategic directions in their Development Strategies, from the economy to digitalisation. Communities held public discussions of SEA drafts, which allows them to involve local residents in shaping environmental policy.

At the same time, there was some uneven access to environmental data during the SEA process, in particular on air quality or the amount of accumulated waste.

Therefore, the technical capacity to model the projected impact of the measures was limited during the SEA.

Thus, the experience of implementing Strategic Environmental Assessment in these communities demonstrates significant progress in the implementation of European environmental approaches at the local level, while also revealing the need to improve information support, training and digital impact assessment tools.

Despite the positive developments in the implementation of strategic environmental assessment at the local level, Ukrainian communities face a number of systemic challenges that make it difficult to fully realise the potential of SEA as a tool for environmental protection and environmentally responsible planning.

1) Lack of up-to-date environmental data. One of the most common problems is the lack of high-quality, localised environmental monitoring. Data on the state of air, water, soil or biodiversity is often general, regional or outdated. In most SEA reports, information on soil conditions is presented only in general terms, without reference to specific areas. This makes it difficult to assess the real impact of strategic measures.

2) Limited technical and human capacity. Most communities carry out SEAs with the participation of external experts, as there are no environmental or urban planning specialists with experience in implementing such procedures in local governments. As a result, communities are not always able to independently monitor or control the implementation of environmental recommendations contained in SEA reports.

3) Formal approach to alternatives and scenario analysis. In some cases, the consideration of alternatives is declarative. Instead of an in-depth analysis of possible scenarios for community development, only the ‘zero scenario’ and the optimistic one are often presented. This reduces the quality of strategic planning and does not allow for a full assessment of the benefits or risks of different areas of strategy implementation.

4) Insufficient integration of the SEA into the decision-making process. In some cases, SEA results have no real impact on changing the content or structure of strategies. This is especially true for communities where the strategy was already almost completed at the time of the SEA, and the procedure was carried out ‘in parallel’ without the possibility of making adjustments. This situation reduces environmental assessment to a formality rather than a management tool.

5) Limited public participation. Despite the existence of public discussion procedures, the actual participation of residents in SEA is low. The reasons for this may include lack of awareness, lack of available feedback tools, and limited communication from the authorities. This prevents local knowledge from being taken into account and increasing trust in the decision-making process.

6) Military challenges and uncertainty. Due to russia's full-scale aggression, communities often operate under conditions of increased uncertainty. Damage to infrastructure, contamination of territories, and violations of sanitary and epidemiological regimes all add a critical new context to the SEA that is not yet sufficiently addressed in the methodological recommendations.

Thus, although SEA in Ukraine is actively developing, there is a need for methodological support, staff training, digital transformation and improvement of the regulatory and information environment.

The development of SEA in Ukraine demonstrates significant progress in promoting an environmentally responsible approach to local development planning. At the same time, the identified challenges indicate the need for comprehensive improvement of both the regulatory environment and practical mechanisms for SEA implementation. The main areas for improving SEA practice at the level of territorial communities include:

1) Development of SEA standards and templates. Many communities face difficulties in organising the SEA process due to the lack of agreed sample documents, examples of reports, and forms for assessing alternatives. The development of a national set of templates (in a step-by-step format) adapted to the strategies typical for territorial communities will help reduce barriers for communities with limited resources.

2) Strengthening the analytical and digital capacity of communities. The introduction of GIS platforms, environmental databases, and mapping of vulnerable areas (green zones, protected areas, aquifers, coastal strips) will significantly improve the quality of analysis in the SEA. Digitisation of environmental information will not only allow for faster assessments, but also for continuous data updates in the course of strategy implementation.

3) Professional development of local specialists. Training programmes should be implemented for local government officials, employees of public utilities, and civic activists involved in SEA. Topics should cover both technical aspects (impact assessment, scenario analysis) and public communication skills.

4) Institutional support and inter-municipal cooperation. Since most communities do not have separate environmental departments, it is advisable to form cluster environmental offices or engage specialists from the oblast level to support SEA procedures. Inter-municipal experience exchange platforms can also be introduced, allowing communities to learn from each other and save resources.

5) Consideration of wartime challenges in the SEA methodology. Full-scale war has created a new context for community development planning. Damage to infrastructure, pollution of territories, and population migration should be taken into account as separate factors of environmental vulnerability. Methodological recommendations need to be updated to reflect these realities.

Conclusions.

Strategic environmental assessment is gradually transforming from a formal requirement into an effective tool that allows integrating environmental priorities, including the preservation of green spaces, into strategic planning at the local level.

It is determined that the key advantages of SEA are the ability to assess potential environmental risks at an early stage, to propose reasonable alternatives, and to ensure public participation in the formation of sustainable development policy. In this regard, the protection of green areas as elements of spatial sustainability and public health is of particular importance.

At the same time, a number of challenges have been identified in the practice of SEA: limited data, lack of specialists, and poor integration of assessment results into strategic documents. In response to this, we are suggest these include the introduction of digital tools, staff training, strengthening inter-municipal cooperation, and updating methodological approaches to take into account the military context.

In summary, SEA is a promising mechanism that allows combining the environmental, social and economic interests of communities. Harnessing its potential is critical in the process of post-war restoration of territories and the formation of environmentally responsible spatial development.

REFERENCES

1. On Strategic Environmental Assessment, Law of Ukraine No. 2354-VIII (2023) (Ukraine). https://zakon.rada.gov.ua/laws/show/2354-19#Text
2. *Directive - 2001/42 - EN - EUR-Lex*. (2001). EUR-Lex — Access to European Union law — choose your language. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:32001L0042
3. On approval of Methodological recommendations for conducting strategic environmental assessment of urban planning documentation, Order No. 705 (2023) (Ukraine). https://zakon.rada.gov.ua/rada/show/v0705926-23#Text
4. Protocol on Strategic Environmental Assessment to the Convention on Environmental Impact Assessment in a Transboundary Context, Protocol United Nations (2015). https://zakon.rada.gov.ua/laws/show/995_b99#Text
5. On Environmental Protection, Law of Ukraine No. 1264-XII (2024) (Ukraine). https://zakon.rada.gov.ua/laws/show/1264-12#Text
6. On Land Protection, Law of Ukraine No. 962-IV (2024) (Ukraine). https://zakon.rada.gov.ua/laws/show/962-15#Text
7. On the Nature Reserve Fund of Ukraine, Law of Ukraine No. 2456-XII (2025) (Ukraine). https://zakon.rada.gov.ua/laws/show/2456-12#Text
8. On the Regulation of Urban Planning Activities, Law of Ukraine No. 3038-VI (2025) (Ukraine). https://zakon.rada.gov.ua/laws/show/3038-17#Text
9. Unified Register of Strategic Environmental Assessment. (n.d.). Home | EcoSystem. https://eco.gov.ua/registers/yedynyi-reiestr-stratehichnoi-ekolohichnoi-otsinky
10. Strategic Environmental Assessment of the Comprehensive Plan. (2022). https://decentralization.ua/uploads/library/file/819/SEO_ready.pdf
11. Community Development Strategy. (2024). Martynivka Village Council. https://martynivka-gromada.gov.ua/strategiya-rozvitku-gromadu-10-46-54-12-06-2024/
12. Development Strategy of the Velykobagachka Community. (2024). Velykobagachka Community. https://velyka-bagachka-rada.gov.ua/strategiya-rozvitku-velikobagachanskoi-gromadi-15-40-34-31-07-2024/
13. *The european green deal*. European Commission. https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en
14. Development Strategy of the Velikorublivska Rural Territorial Community. (2024). Velikorublivska Community. https://velykorublivska-gromada.gov.ua/docs/1643908/

According to the Scientific Edition
Candidate of Biological Sciences
Professor
Melnyk T.I.

Monograph

SPATIAL RELATIONSHIPS AND MANAGEMENT SYSTEMS IN FOREST, PARK, AND AGRICULTURAL COMPLEXES IN THE CONTEXT OF MODERN CHALLENGES AND SUSTAINABLE DEVELOPMENT

Published: 09.05.2025.
Typeface: Times New Roman.
RS Global Sp. z O.O., Warsaw, Poland, 2025
Numer KRS: 0000672864
REGON: 367026200
NIP: 5213776394